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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

INCLUDING THE

PROGRAMME OF THE

1960 WINTER MEETING IN THE WEST

AT THE

UNIVERSITY OF CALIFORNIA, BERKELEY

December 29–31, 1960

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December 29, 1960 Series II, Vol. 5, No. 7

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

1960 Winter Meeting in the West, University of California, Berkeley, December 29–31, 1960

THE 1960 **Winter Meeting in the West** will be held in Berkeley on the campus of the University of California, with the Department of Physics acting as host. The days of Thursday, Friday, and Saturday, December 29, 30, and 31, 1960, are assigned to regular sessions of the Society. The days of Tuesday, Wednesday, and Thursday, December 27, 28, and 29, 1960, will be assigned to a nuclear-physics topical conference on **Strong Interactions,** the programme of which (comprising invited papers only) will be found in the back of this Bulletin. The conference is open to all members of the Society. Special information concerning the conference is given in a separate announcement on page 515.

Registration for the regular meeting will take place on Thursday morning in the open hall area, first floor, of the new part of the Le Conte Physics Building. There will be a registration fee of one dollar. Detailed information concerning accommodations, messages, bus transportation, sightseeing trips, and other activities will be available at desks in this area. Great credit is due our Local Committee Chairman, Professor Howard Shugart, for his efficient arrangement of local details for the meeting. Any questions concerning local details of the meeting may be referred to Professor Shugart or to those who are assisting in the area of registration tables.

A **programme for the ladies** is being planned, including a luncheon and sightseeing trip. Further information will be available at registration time.

Advance notice is given to those ladies who wish to take a "three-bridges" (Richmond-San Rafael, Golden Gate, and Oakland Bay) bus tour. This trip will leave Le Conte Hall at 10:30 a.m., Thursday, December 29, and return to Le Conte Hall at about 4:30 p.m. after visiting points of interest in Marin County and San Francisco. Coffee hours for the ladies will be held from 10 a.m. to 12 noon on Tuesday, December 27, and Friday, December 30.

The **Banquet** of the Society will be held at the Claremont Hotel on Friday at 7:00 p.m., preceded by a Cocktail Hour between 6:00 and 7:00 p.m. Tickets for the banquet and Cocktail Hour will be distributed at the registration desk. The cost of the banquet is $4.50 per person. No banquet tickets will be sold after 12:00 noon on Friday. Tickets should be purchased as soon as possible, as space is limited. Professor Emilio Segrè, recent Nobel laureate, will give the after-dinner speech: it is entitled "Teaching of Physics." The Society is indebted to various West Coast industrial firms for their generous sponsorship of the Cocktail Hour. Special tickets indicating the sponsors will be issued for the Cocktail Hour.

A variety of **accommodations** is available for all who attend either or both the topical conference on Strong Interactions and the meeting of the Society. Blocks of rooms are reserved in Berkeley at the Hotels Shattuck, Durant, and Claremont, and at motels Berkeley Plaza, Berkeley Travelodge, California, and Berkeley Flamingo. Please note that December 15 is the deadline date for reservations of the above accommodations; thereafter you will not be given any special consideration. Reservations must be requested by letter to the hotel in which it is made clear that you are attending the Berkeley meeting of The American Physical Society. Rooms in Berkeley should be reserved as soon as possible, and probably some sharing of rooms will be necessary. Those who prefer to stay in San Francisco will find relatively convenient bus service from San Francisco to Berkeley and return.

The newly opened cafeteria at the Student Union and the regular buffet facilities at the Men's Faculty Club will be available for lunches.

The regular programme of the Society will consist of 111 contributed papers and 24 invited papers. The invited programs were arranged with the assistance of a Committee comprised of Professors C. Kittel, G. F. Chew, I. Perlman, W. A. Nieren-

berg, R. R. Brown, and Dr. E. Edelsack. Sessions of invited and contributed papers will be held in several lecture rooms in the Physics Building and Le Conte Hall and in Wheeler Auditorium. The various sessions cover a wide variety of topics including nuclear physics, theoretical physics, general solid-state physics, resonance physics, molecular beams, gas ion physics, helium physics, astrophysics, and biophysics.

Post-deadline papers of sufficient importance to warrant their inclusion in a special supplementary programme will be considered by the Local Deputy Secretary if the abstracts are received no later than Monday, December 19, at the Office of the Deputy Secretary for the Pacific Coast, E. L. Hahn, Department of Physics, University of California, Berkeley 4, California. Such as are accepted will be presented at the ends of contributed-paper sessions and will be listed on a blackboard near the registration desk in Le Conte Hall.

Errata pertaining to the contents of this issue will be published in a later issue of this Bulletin if received not later than Tuesday, January 3, by Miss Ruth F. Bryans, Special Publications, American Institute of Physics, 335 East 45th Street, New York 17, New York. Do not send in your abstract marked with corrections! Write out your corrections in the form "instead of . . . read . . . ." Alternatively you may say "The sentence beginning with the words . . . is to be rewritten as follows . . . ." Add nothing. The privilege of inserting errata is not accorded to enable people to publish additional data or to restore material cut out because the abstract was too long.

E. L. HAHN, *Deputy Secretary for the Pacific Coast*
Department of Physics
University of California
Berkeley 4, California

EPITOME OF THE 1960 WINTER MEETING IN THE WEST AT THE UNIVERSITY OF CALIFORNIA, BERKELEY

(Personal names are those of invited speakers.)

Thursday Morning

9:30 A. Ferromagnetism and spin resonance; Suhl. 1 Le Conte Hall.
10:00 B. Astrophysics; Weaver, Minkowski, Warwick. 310 Le Conte Hall.
9:30 C. Low-energy nuclear physics I. 4 Le Conte Hall.
9:30 CA. Division of Electron Physics; Gerjuoy, Bederson, Hagstrum, Clark. 312 Le Conte Hall.

Thursday Afternoon

2:00 D. Experimental Biophysics; Tobias, Sinsheimer, Enstrom. 1 Le Conte Hall.
2:00 E. Microwave resonance; Kip, Portis, Pake, Jeffries. 310 Le Conte Hall.
2:00 F. General physics I. 4 Le Conte Hall.

Friday Morning

10:00 G. Theoretical nuclear physics; Pais, Gell-Mann, Weinberg. Wheeler Auditorium.
9:30 H. Magnetic resonance; Townes. 310 Le Conte Hall.
10:00 I. General physics II. 1 Le Conte Hall.
10:00 J. Low-energy nuclear physics II. 4 Le Conte Hall.

Friday Afternoon

2:00 K. Helium and phonon physics; Brueckner, Fairbank, Bömmel, Hubner. 1 Le Conte Hall.
1:30 L. Molecular beam and gas ion physics; Marrus. 312 Le Conte Hall.
1:30 M. Theoretical physics. 310 Le Conte Hall.
2:00 N. Solid state, semiconductors. 4 Le Conte Hall.

Friday Evening

7:00 Banquet of The American Physical Society; Segrè. Claremont Hotel.

Saturday Morning

9:30 O. High-energy nuclear physics. 310 Le Conte Hall.
9:30 P. Low-energy nuclear physics; Stephens, Nilsson, Halpern, Glendenning. 1 Le Conte Hall.
9:30 Q. Solid state, shock waves. 4 Le Conte Hall.

PROGRAMME

THURSDAY MORNING AT 9:30

1 Le Conte Hall

(F. REIF presiding)

Ferromagnetism and Spin Resonance

Invited Paper

A1. Hyperfine Field as a Probe in Magnetic Materials. H. SUHL, *University of California, Berkeley, and Bell Telephone Laboratories.* (30 min.)

Contributed Papers

A2. Co^{59} NMR in Single Domain Cobalt Particles. R. H. LINDQUIST, *California Research Corporation*, AND A. C. GOSSARD, A. M. PORTIS, AND M. RUBINSTEIN, *University of California, Berkeley.*—Two distinct nuclear resonances have been observed in small (400-A diameter) fcc cobalt particles prepared by reduction on a high area Al_2O_3 surface. At room temperature and in zero applied magnetic field the resonances are centered at 213.1 and 217.0 Mc/sec. Their half-widths are about 400 and 800 kc/sec, respectively. The low-frequency resonance is in all respects identical with the resonance previously observed from nuclei in domain walls. We interpret the high-frequency resonance as arising from nuclei in single domain particles where the resonance is excited by domain rotation. Within a spherical single domain particle there is a demagnetizing field $-4\pi M/3$, which is not present in domain walls. Since the hyperfine field itself is negative, the effect of the demagnetizing field should be to raise the resonance frequency. One expects on this argument a splitting of 5.6 Mc/sec. The somewhat reduced splitting and the large line width of the single domain resonance is attributed to interaction between cobalt particles. In an applied magnetic field the high-frequency resonance drops at nearly 1 Mc/sec per koe; the low-frequency resonance is unshifted by a field although its intensity is markedly reduced. This behavior is completely as expected with the indicated interpretation.

A3. Temperature Dependence of the Nuclear Magnetic Resonance of Ni^{61} in Pure Nickel. L. J. BRUNER, J. I. BUDNICK, R. J. BLUME, AND E. L. BOYD, *IBM Watson Laboratory.*—We recently have made the first observation of the NMR of Ni^{61} in metallic nickel.[1] The variation with temperature of the Ni^{61} NMR frequency has been measured from 77°K to 450°K. The specimen material was 99.999% pure Johnson-Matthey nickel powder having the natural isotopic abundance (1.25%) of Ni^{61}. In the range studied the temperature dependence of the NMR frequency may be fitted approximately by an expression of the form

$$\nu(T)=\nu_0+\nu_1[1-(T/T_c)^2]^{\frac{1}{2}},$$

where $\nu_0=9.15$ Mc, $\nu_1=19.20$ Mc, and the Curie temperature T_c is 631°K. The relationship of these results to the temperature dependence of the saturation magnetization, as given by the collective electron model of a ferromagnet, will be discussed.

[1] L. J. Bruner, J. I. Budnick, and R. J. Blume, Phys. Rev. (to be published).

A4. Nuclear Magnetic Resonance of Fe^{57} and of Ni^{61} in Iron-Nickel Alloys. J. I. BUDNICK, L. J. BRUNER, E. L. BOYD, AND R. J. BLUME, *IBM Watson Laboratory.*—The NMR of Fe^{57} has been observed in dilute alloys of nickel in iron. Similar observations of the Ni^{61} resonance in dilute alloys of iron in nickel also have been made. All measurements were made at room temperature. The addition of iron to pure nickel raises the internal field at the nickel nucleus, as evidenced by a rapid increase in the Ni^{61} resonant frequency. At the iron rich end, the change in the Fe^{57} resonant frequency is much less for corresponding additions of nickel. In the very dilute region, i.e., for compositions of less than 5% of either solute, the variation of the internal field seems to be qualitatively similar to the variation in saturation magnetization of these alloys.

A5. Nuclear Magnetic Resonance of Ni^{61} in Nickel Metal. RALPH L. STREEVER, JR., AND LAWRENCE H. BENNETT, *National Bureau of Standards.*—The nuclear magnetic resonance of Ni^{61} has been observed in 99.97% pure unenriched nickel powder. The resonance occurs at a frequency of 26.1 Mc/sec at room temperature with a line width of about 50 kc/sec. Contrary to the observations of Bruner, Budnick, and Blume,[1] the temperature dependence of the frequency was found to be in reasonable accord with the expression

$$\nu=\nu_0[1-(T/T_c)^2]^{\frac{1}{2}}.$$

Application of a magnetic field causes a decrease in the intensity of the resonance, but no measurable shift in frequency. Approximately 1000 oe are required to reduce the intensity to between one-half and two-thirds of the zero field intensity. The Ni^{61} resonance also was observed in 99.7% nickel with substantially the same results as with the purer sample. Studies are in progress on the resonance in nickel-rich alloys.

[1] The Ni^{61} resonance was first observed by L. J. Bruner, J. I. Budnick and R. J. Blume (private communication) in 99.999% pure nickel.

A6. Spin Echo Studies of Ni^{61} in Ferromagnetic Nickel.* M. WEGER, E. L. HAHN, AND A. M. PORTIS, *University of California, Berkeley.*—Spin-echo signals have been observed from Ni^{61} nuclei in finely divided multi-domain nickel particles. The resonance frequency corresponds to a hyperfine field of 185 000 oe as reported by Budnick, Bruner, and Blume.[1] Spin-spin and spin-lattice relaxation have been studied by spin-echo techniques in both a natural sample (1.25% Ni^{61}) and a highly enriched sample (94.37% Ni^{61}). The resonance line width as determined from the width of the spin-echo is 220 kc/sec at helium temperatures with some reduction at 77°K and above. In the enriched sample the contribution of spin-spin coupling to the transverse relaxation time is 0.25 msec as measured at both 77° and 295°K. The spin-spin coupling observed in natural nickel is consistent with a relaxation rate proportional to the Ni^{61} concentration. The spin-lattice relaxation time is approximately $80/T$ msec at both 1.5° and 4.2°K as measured in natural nickel.

* Supported by the Office of Naval Research and the U. S. Atomic Energy Commission.

[1] L. J. Bruner, J. I. Budnick, and R. J. Blume (private communication).

A7. Intrinsic Relaxation of the Uniform Mode in YIG via Higher Spin Wave Branches. P. PINCUS AND H. SUHL, *University of California, Berkeley.*—Experiments by Le Craw[1] *et al.* have shown that, at temperatures greater than about 100°K, the relaxation rate of $k=0$ spin waves in high-polished, ultra-pure YIG *increases* linearly with frequency and with a temperature dependence of T^n, $n\geq 2$. Spin wave processes involving only the usual low lying spin wave branch cannot exhibit the observed frequency dependence. We have shown, however, that second-order 3 magnon dipolar processes via the higher spin wave branches of a ferrimagnet will exhibit the frequency dependence observed by Le Craw. The temperature dependence and order of magnitude of the relaxation rate are not inconsistent with his experiments, assuming reasonable values for the energy gaps to the upper branches. Note that this relaxation will occur even in a perfect ferrimagnet.

[1] Le Craw (private communication).

A8. Antiferromagnetic Resonance in MnO at Submillimeter Wavelengths.* A. J. SIEVERS, III, *University of California, Berkeley.*—The transmission of MnO powder has been investigated at far infrared wavelengths and at temperatures from 1.5°K to above the Néel temperature (120°K). At the lowest temperature a resonance was observed at 27.5 ± 0.3 cm^{-1} with a line width that could not be resolved by the apparatus. As the temperature was increased, the resonance frequency decreased as the square root of a Brillouin function of spin $\frac{1}{2}$. A magnetic field of 10 000 oe applied to 1.5°K had no observable effect. These results are consistent with a model due to Keffer and O'Sullivan[1] in which the dipolar anisotropy confines the spins to a (111) plane, and a much weaker anisotropy orients the spins within this plane. The temperature dependence of the resonance can be explained using simple macroscopic theory.

* Supported in part by the A. P. Sloan Foundation, the National Science Foundation, and the Office of Naval Research.
[1] F. Keffer and W. O'Sullivan, Phys. Rev. **108**, 637 (1957).

A9. Strong Field Low-Temperature Studies of the Magnetization of Europium Metal. WARREN E. HENRY,* *U. S. Naval Research Laboratory.*—An experimental study of the magnetization of europium metal has been carried out in magnetic fields up to 106 000 gauss and at temperatures of 295°K, 77.4°K, and 4.2°K. This research was undertaken to extend high field research on hexagonal close-packed lanthanide ($4f$ unpaired electrons) metals[1] to a $4f$ face-centered cubic system, europium. A low field slope of 1.3×10^{-4} Bohr magneton per gauss-atom in the magnetization curve for 4.2°K decreases with increasing field, increases, and then decreases. The magnetization in a field of 75 000 gauss is 0.46 Bohr magneton per atom at 295°K and 1.36 Bohr magnetons per atom at 77.4°K. At 106 000 gauss the magnetization is 2.27 Bohr magnetons per atom at 4.2°K. The hysteresis loop is small, amounting to a width of 5% at 40 000 gauss and 4.2°K. The remanence is 0.03 Bohr magneton per atom at 4.2°K and 0.07 Bohr magneton per atom at 1.3°K. The coercive force is 100 gauss at 4.2°K and 300 gauss at 1.3°K. A sample displacement, ballistic method was used for measuring the magnetization. Nickel was used in the calibration.

* Now at Lockheed Missiles and Space Division.
[1] W. E. Henry, Phys. Rev. **117**, 89 (1960); J. phys. radium **20**, 192 (1959); J. Appl. Phys. **31**, 323S (1960); *ibid.* **30**, 99S (1959); *ibid.* **29**, 524 (1958).

A10. Approximate Solution of the Density Matrix. HYMAN SERBIN, *Hughes Aircraft Company.*—Bloch's equation is solved in an approximate way analogous to the WKB procedure. The density matrix is represented as the product of an exponential of $W/\hbar$ by a function A analytic in $\hbar$. The function W and the coefficients of A are obtainable by the solution of a system of first-order partial differential equations. The solutions of the latter are reduced to solutions of ordinary differential equations in one independent variable. The case of a free particle and a simple harmonic oscillator are discussed, and it is found that the lowest order approximation yields the exact result.

A11. Lattice Contributions to the Electric Field Gradients in H. C. P. Metals and Indium. T. P. DAS,* *Government of India Atomic Energy Establishment, Bombay,* AND M. POMERANTZ, *IBM, Yorktown.*—The analytic method of Nijboer and de Wette[1] has been used to calculate the electric field gradients produced by point charges (ionic cores) on the lattice sites in a series of hexagonal close-packed metals and indium. In the former, the field gradients are found to be a strong function of the axial ratios c/a, and a curve of q vs c/a will be presented. The calculated field gradients are combined with experimental values of e^2qQ and those values of Q that are known to demonstrate a rule that at the ideal $c/a=1.633$ the metals are most nearly ideally metallic in the sense that they have least covalent character. In indium the ionic field gradient is small compared to the observed field gradient,[2] implying that the field gradient arises mostly from unbalanced p electrons.

* Worked performed at Department of Chemistry, Columbia University, under a U. S. Atomic Energy Commission contract.
[1] F. W. de Wette and B. R. A. Nijboer, Physica **24**, 1105 (1958) and references therein.
[2] R. R. Hewitt and W. D. Knight, Phys. Rev. Letters **3**, 18 (1959).

THURSDAY MORNING AT 10:00

310 Le Conte Hall

(R. B. BRODE presiding)

Invited Papers on Astrophysics

B1. Radio Radiation from the Galaxy. HAROLD F. WEAVER, *University of California, Berkeley.* (30 min.)

B2. Radio Sources. RUDOLPH MINKOWSKI, *Mt. Wilson and Palomar Observatories.* (30 min.)

B3. Interaction of Solar Corpuscles and the Magnetic Field of Jupiter. JAMES W. WARWICK, *High Altitude Observatory.* (30 min.)

THURSDAY MORNING AT 9:30

4 Le Conte Hall

(HANS MARK presiding)

Low-Energy Nuclear Physics. I

C1. Level Structure of Be^8 from $Li^7(d,n)Be^8$.* F. S. DIETRICH† AND L. CRANBERG, *Los Alamos Scientific Laboratory.*—Time-of-flight methods have been used to observe neutrons from $Li^7(d,n)Be^8$ with deuterons of several energies from 3.59 to 7.25 Mev. States in Be^8 are noted with $E_x=0$, 2.9, 16.64 ±.015, 16.9±.05, 17.64, and 18.15 Mev. Strongly forward-peaked angular distributions were found for the 16.64-, 17.64-, and 18.15-Mev levels, indicating direct interaction is strongly present. Distorted-wave stripping calculations with $l=1$ angular momentum transfer fit the observed stripping patterns well for the 16.64-Mev level; this is consistent with the $J^\pi=2^+$ and $T=1$ assignments for this level. Cross sections for the stripping reactions are essentially independent of energy and are (in mb/sr at 0° in the cm system, and with an accuracy of 10%): 16.64 Mev, 23; 17.64, 7; 18.15, 10. The 16.9-Mev level is isotropic, indicating compound nucleus formation, and has the relatively low total cross section of 11±5 mb.

* This work performed under the auspices of the U. S. Atomic Energy Commission.
† Now at California Institute of Technology.

C2. Energy Levels of Na^{21} and Mg^{22}.* F. AJZENBERG-SELOVE, *Haverford College,* AND L. CRANBERG AND F. S. DIETRICH,† *Los Alamos Scientific Laboratory.*—Neon gas has been bombarded with 2.4-, 3.1-, 4.6-, and 6.1-Mev deuterons and with 3.4- and 4.5-Mev He^3 particles. At least six states of Na^{21} with $E_x<4$ Mev have been observed by time-of-flight measurements of neutron groups: the first excited state is at 0.37±0.05 Mev. Angular distributions show strong direct interaction features. Mg^{22}, here observed for the first time, has a mass excess $(M-A)$ of −0.09±0.08 Mev (C^{12} reference) from $Q=-0.09\pm0.08$ Mev for $Ne^{20}(He^3,n)Mg^{22}$. The first excited state is at 0.99±0.05 Mev. No other states are observed with $E_x<2.5$ Mev.

* Research supported by the U. S. Atomic Energy Commission and by the National Science Foundation.
† Now at California Institute of Technology.

C3. Reactions $Li^6(\alpha,d)Be^8$ and $Li^7(\alpha,d)Be^9$ with 48-Mev Helium Ions.* J. CERNY, B. G. HARVEY, AND R. H. PEHL, *Lawrence Radiation Laboratory, Berkeley.*—In a continuing study of the (α,d) reaction in the light elements the deuteron energy spectra and angular distributions have been determined from bombardment of Li^6 and Li^7. Deuterons were identified by means of an $E-(dE/dx)$ counter telescope and pulse multiplying circuit. A silicon diffuse junction detector has replaced the CsI photomultiplier unit as the dE/dx component producing much better resolution of the multiplied (p,d,t) peaks. Angular distributions of deuterons to the ground states of Be^8 and Be^9 and to the 2.90-Mev level of Be^9 have been obtained. The two-particle—plane wave, finite incident particle—stripping theory of Glendenning[1] has been applied to these data. Energy spectra, angular distributions, and comparisons with the theory will be shown.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] N. K. Glendenning, Nuclear Phys. (to be published).

C4. Comparison of the Reactions $C^{12}(He^3,n)N^{14}$ and $C^{12}(\alpha,d)N^{14}$.* B. G. HARVEY, J. CERNY, AND R. H. PEHL, *Lawrence Radiation Laboratory, Berkeley.*—The reactions $C^{12}(He^3,p)N^{14}$ and $C^{12}(\alpha,d)N^{14}$ both involve the stripping of a proton and a neutron from the incident particle and their transfer to the target nucleus. In previously reported work,[1] the (α,d) reaction was studied, using 48-Mev incident ions. We have measured the energy spectra of protons from the (He^3,p) reaction, using 31-Mev He^3 ions from a linear accelerator. The proton and deuteron spectra are remarkably similar. In both reactions, the ground state and 3.95-Mev state of N^{14} are produced in small yield. The spectra both contain two intense particle groups corresponding to the formation of groups of N^{14} levels at excitation energies of 5.8 and 8.5 Mev. The 2.31-Mev $T=1$ level of N^{14} is absent from the (α,d) spectrum, but the level is excited to an extent comparable to the ground state and 3.95-Mev state in the (He^3,p) reaction.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] B. G. Harvey and J. Cerny, Phys. Rev. (to be published).

C5. (p,α) Reactions on Li^6 and Li^7.* J. ALSTER AND J. GONZALEZ-VIDAL, *Lawrence Radiation Laboratory, Berkeley.*—Li^6 and Li^7 targets have been bombarded with 12-Mev protons from the Crocker Laboratory 60-in. cyclotron. The angular distributions of He^4 and He^3 from $Li^6(p,\alpha)He^3$ and He^4 from $Li^7(p,\alpha)\alpha$ have been measured. A solid-state radiation detector in anti-coincidence with a CsI crystal has been used. The $Li^6(p,\alpha)He^3$ differential cross sections show strong forward and backward peaking indicating the presence of at least two direct interaction mechanisms. Combination of He^3 and He^4 differential cross sections show the angular distribution for either of these particles from 10° to 170° (C.M.) The $Li^7(p,\alpha)\alpha$ differential cross section exhibits symmetry around 90° (C.M.) as expected for identical particles. Analysis of the experimental data shows direct interaction characteristics for the angular distribution. A discussion of several possible mechanisms for the reaction will be presented.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

C6. $Be^9(e,n)$ and (γ,n) Cross Section from Threshold to 5 Mev. MARK J. JAKOBSON, *Montana State University.*—The electrodisintegration cross section of Be^9 has been measured by bombarding a 30-mil target with monoenergetic electrons. The neutrons from the disintegrations were detected by a BF_3 long counter imbedded in paraffin. The $Be^9(e,n)$ cross section, when plotted vs electron energy, rises with increasing slope from threshold to a value of 7.0±1.0 μb at 5 Mev. The photodisintegration cross section was obtained using a photon difference method. A thick Be target was bombarded with the bremsstrahlung provided by monoenergetic electrons striking a 1-mil Ta target. The photodisintegration cross section rises rapidly from threshold to a maximum of 1.15±0.15 mb at 1.71 Mev, exhibits a minimum at 2.1 Mev, a slight peak at 2.40 Mev, rises to a maximum of 13.0±0.20 mb at 2.95 Mev, decreases to a broad minimum at 3.9 Mev, increases again to a maximum of 1.40±0.40 mb at 4.6 Mev, and then decreases. The significance of these measurements with respect to the energy level diagram of Be^9 will be discussed.

C7. Gamma-Gamma Directional Correlation in Ba^{136}. H. BERNSTEIN AND H. H. FORSTER, *University of Southern California.*—The directional correlation of the 1.065-Mev—0.830-Mev gamma-gamma cascade in Ba^{136} has been studied with a scintillation crystal spectrometer, using two 1½-in. ×1½-in. thallium activated sodium iodide crystals and a fast-slow coincidence circuit of 14-mμsec resolving time. The radioactive source material was $Cs^{136}(13d)$ obtained by exposing metallic lanthanum to the neutron flux of the Chalk River pile. Thin uniform sources were prepared by dissolving Cs^{136} in concentrated hydrochloric acid and then depositing CsCl on films of tygon or polyethylene. The experimental data give for the Legendre polynomial expansion coefficients: $A_2=0.125\pm0.022$ and $A_4=0.007\pm0.033$, thus favoring a 2-2-0 assignment with dipole-quadrupole mixing in the first transition. The quadrupole content for this transition has been determined as $2.7\pm0.7\%$. No evidence for a cross-over transition from the 1.9-Mev level to the ground state has been observed.

C8. Neutron Transfer to Excited States in N^{15} in the N^{14},N^{13})N^{15} Reaction. KENNETH S. TOTH, *Oak Ridge National Laboratory.*—The angular distribution of N^{13} produced in the neutron-transfer reaction, $N^{14}(N^{14},N^{13})N^{15}$, was investigated from 6° to 60° c.m. with 28-Mev N^{14} ions from the Oak Ridge 63-in. cyclotron. Concentric circular strips of aluminum foil placed at a known distance from the target and each encompassing a known angular increment were used to stop the radioactive N^{13} (10 min). Excited states in N^{13} are unstable with respect to proton emission; the first excited state in N^{15} is 5.28 Mev above ground. Therefore, N^{13} nuclei resulting from transfers to the ground state of N^{15} are at least 5 Mev more energetic than those resulting from transfers to N^{15} excited states. The two groups of N^{13} particles can be distinguished by placing suitable absorbers in front of the aluminum catcher foils. It was found that transfers to excited states become more abundant relative to ground state transfers as the incident N^{14} energy is lowered.

C9. Photoneutron Cross Sections for Pb, Ta, and Be.* F. D. SEWARD, C. P. JUPITER, R. E. SHAFER, AND S. C. FULTZ, *Lawrence Radiation Laboratory, Livermore.*—Photoneutron cross sections for Pb, Ta, and Be have been measured in the energy range from 10 to 17 Mev, using nearly monoenergetic photons.[1] The photons were obtained from the annihilation-in-flight of positrons in a 0.030-in. Be target. The positrons were created in a Ta target which was placed between the sections of a 20-Mev linear electron accelerator. The first section of the accelerator was used to accelerate electrons to an energy of 10 Mev, while the second section accelerated positrons to the energy range desired. The momentum of the positrons was selected by an analyzing magnet, and the positron beam was focused with the aid of quadrupole magnets. Measurements on the photoneutron total cross section of Ta yielded two maxima in the giant resonance having peak cross sections of 520 and 720 b and energies of 12.5 and 15.6 Mev, respectively. The giant resonance for Pb was found to have a peak value of 960 b at 13.8 Mev. Some structure has been observed in the measured total cross section for Be and is in general agreement with results previously obtained at other laboratories.

* Work was performed under auspices of the U. S. Atomic Energy Commission.

[1] C. P. Jupiter, N. E. Hansen, R. E. Shafer, and S. C. Fultz, UCRL-6044 (1960).

C10. Capture-to-Fission Ratios for Fast Neutrons in U^{233}, U^{235}, Pu^{239}. J. C. HOPKINS AND B. C. DIVEN, *Los Alamos Scientific Laboratory.*—The ratio of neutron capture and fission cross sections, α, has been measured for U^{233}, U^{235}, and Pu^{239} as a function of neutron energy from 175 kev to 900 kev. A pulsed and collimated neutron beam is passed through the target at the center of a large cadmium-loaded liquid scintillator.[1] Captures and fissions are detected by means of their prompt gamma rays; elastic and inelastic scattering events are ignored because of their smaller pulse heights. Capture events are distinguished from fission events by an anti-coincidence circuit that rejects prompt pulses that are followed, within 32 μsec, by any other pulse. Fission events are usually followed by delayed pulses from the capture of thermalized fission neutrons. Corrections are applied for the fission events not followed by delayed neutron pulses and for the effect of background counts. The capture, capture plus fission, and background events are recorded simultaneously. This procedure yields values of $(1+\alpha)$ to an accuracy of 1%.

[1] B. C. Diven, J. Terrell, and A. Hemmendinger, Phys. Rev. 109, 144 (1958).

C11. Reactor Production, Cross Sections, and Decay of the Pm^{148} Isomers.* R. P. SCHUMAN, J. R. BERRETH, R. L. HEATH, AND C. W. REICH, *Phillips Petroleum Company.*—Samples containing both Pm^{148} isomers were produced by irradiating Pm^{147} in the Materials Testing Reactor. To obtain thermal cross sections and resonance integrals, both Cd-shielded and unshielded irradiations were made in the same reactor position. Gold (resonance integral = 1558 b) served as the resonance flux monitor. The cross section values for the formation of 5.3-d Pm^{148} from Pm^{147} are $\sigma_{th}=124\pm12$ b and $\int\sigma(E)dE/E=1700\pm170$ b; and for the formation of 42-d Pm^{148} are $\sigma_{th}=108\pm11$ b and $\int\sigma(E)dE/E=1570\pm160$ b. A reactor cross section of $23\,000\pm5000$ b was obtained for the burnup of 42-d Pm^{148} from the buildup of the isomer and the production of 53-hr Pm^{149} during the high flux (thermal to resonance flux, $\phi/\theta=\sim30$) irradiation of Pm^{147}. Gamma-ray singles and coincidence spectra were obtained using chemically purified samples. Gamma rays were observed for 5.3-d Pm^{148} at 555 kev (0.30), 910 kev (0.17), and 1460 kev (0.24); and for 42-d Pm^{148} at 85 kev (0.02), 105 kev (0.03), 290 kev (0.15), 420 kev (0.25), 555 kev (1.00), 625 kev (0.98), 725 kev (0.33), 915 kev (0.20), and 1020 kev (0.23); values in parentheses are relative gamma-ray intensities. The 42-d isomer has an ~5% isomeric transition decay branch. Decay schemes are proposed for both isomers.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

C12. Polarization in P-He^4 Scattering at 22-Mev. A. NIR,* H. E. CONZETT, AND G. IGO, *Lawrence Radiation Laboratory, Berkeley.*—The left-right asymmetry in the scattering of polarized 22-Mev protons from helium has been measured at 30, 45, 60, 75, 82, and 105 deg in the laboratory system. The polarized protons are produced in the reaction $H'(He^4,P)He^4$ with 48-Mev alpha particles incident on a hydrogen gas target. The protons knocked on at an angle of 25 deg with respect to the incident beam are approximately 100% polarized.[1] Comparison will be made with polarizations calculated from phase shifts derived mainly from analyses of differential cross-section data.[2]

* On leave of absence from the Weizmann Institute of Science, Rehovoth, Israel.

[1] L. Rosen and J. E. Brolley, Jr., Phys. Rev. 107, 1454 (1957).

[2] J. L. Gammel and R. M. Thaler, Phys. Rev. 109, 2041 (1958).

THURSDAY MORNING AT 9:30

312 Le Conte Hall

(RONALD GEBALLE presiding)

Invited Papers of the Division of Electron Physics

CA1. Atomic Scattering Processes. EDWARD GERJUOY, *Plesset Associates.* (30 min.)
CA2. Recent Experiments on the Scattering of Electrons from Alkalies. BENJAMIN BEDERSON, *New York University.* (30 min.)
CA3. Electron Ejection by Auger Neutralization of Ions at Solid Surfaces. HOMER D. HAGSTRUM, *Bell Telephone Laboratories.* (30 min.)
CA4. Spectroscopy of Late Afterglows. K. C. CLARK, *University of Washington.* (30 min.)

THURSDAY AFTERNOON AT 2:00

1 Le Conte Hall

(E. A. EDELSACK presiding)

Invited Papers on Experimental Biophysics

D1. Biophysical Studies of Cell Division. C. TOBIAS, *University of California, Berkeley.* (30 min.)
D2. Biophysical Approaches to the Study of Bacteriophage Reproduction. R. L. SINSHEIMER, *California Institute of Technology.* (30 min.)
D3. Bone and Radiation. A. ENGSTROM, *Karolinska Institute, Stockholm.* (30 min.)

THURSDAY AFTERNOON AT 2:00

310 Le Conte Hall

(E. L. HAHN presiding)

Invited Papers on Microwave Resonance

E1. Cyclotron Resonance in Metals. A. F. KIP, *University of California, Berkeley.* (30 min.)
E2. Microwave Resonance in Canted Antiferromagnets. A. M. PORTIS, *University of California, Berkeley.* (30 min.)
E3. Paramagnetic Relaxation in Crystalline Free Radicals. G. E. PAKE, *Stanford University.* (30 min.)
E4. Dynamic Proton Polarization. C. D. JEFFRIES, *University of California, Berkeley.* (30 min.)

THURSDAY AFTERNOON AT 2:00

4 Le Conte Hall

(J. REYNOLDS presiding)

General Physics I

F1. Diffusional Transport of Atomic Hydrogen through Molecular Hydrogen at Elevated Temperatures.*—HENRY WISE, *Stanford Research Institute.*—Changes in the transport properties of a gas mixture of atomic and molecular hydrogen were determined in a temperature range from 300°K to 700°K. The steady-state distribution of atoms diffusing from a source (an electrodeless discharge in H_2) towards a catalytically active surface was measured in a cylinder of finite length.[1,2] The experimental parameter of interest is the diffusion Reynolds number[2] δ which contains the ratio of interdiffusion coefficient D_{ij} to recombination coefficient. If the catalytic activity of the surface is known, one may relate the atom-concentration gradient to the diffusion coefficient. In the temperature region studied the binary diffusion coefficient

for the system H,H_2 is given by $D_T = D_0(T)$[1]. Based on the results obtained, the intermolecular force fields applicable to the atom-molecule encounters are examined.

* Sponsored by Project SQUID supported by the Office of Naval Research, Department of the Navy.
[1] H. Wise and C. M. Ablow, J. Chem. Phys. **29**, 634 (1958).
[2] H. Wise, J. Chem. Phys. **31**, 1414 (1959).
[3] H. Motz and H. Wise, J. Chem. Phys. **32**, 1893 (1960).

F2. Diffusion of Helium through Kovar. JOSEPH LIPSON AND HENRY GLYDE, *University of Alberta*.—Preliminary measurements have been made in the temperature range of 600°K to 1000°K. The activation energy for diffusion was found to vary greatly over the course of the measurements indicating that the history of the sample is important. Typical diffusion coefficients obtained are

Temp. °K	$d(\text{cm}^2\ \text{sec}^{-1})$
828	2×10^{-6}
1041	5×10^{-6}

F3. Attainment of Ultra-High Vacuum in an Unbaked System by Molybdenum Evaporation.* A. L. HUNT, C. C. DAMM, AND E. C. POPP, *Lawrence Radiation Laboratory, Livermore*.—The deposition of molybdenum by evaporation from simple hairpin filaments has been found to reduce the pressure in an 85-liter stainless steel system to 4×10^{-10} mm Hg. The pressure was measured by means of two Bayard-Alpert type ionization gauges mounted within the volume. The system was metal gasketed and initially evacuated to 1×10^{-7} mm Hg with a small, well-trapped diffusion pump which remained on at all times. The geometrical area of the molybdenum substrate was 8×10^3 cm², or about 75% of the total surface. Evaporation of 0.3 g of molybdenum was sufficient to maintain a pressure below 1×10^{-9} mm Hg for more than 40 hr. After evaporation, a pressure increase of 1×10^{-10} mm Hg above the base reading was maintained for a period of 20 min with a hydrogen influx of 8×10^{-6} mm *l*/sec, indicating an average sticking probability of 0.2. Higher values of the sticking probability were observed for shorter times on freshly evaporated coatings.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

F4. Sensitivity of the Field-Ion Vacuum Gauge to Several of the Permanent Gases.* GEORGE BARNES AND JERRY L. GAINES, *University of Nevada*.—Experimental determination of the sensitivity of the cold-cathode vacuum gauge employing field-ion emitters[1] to some of the permanent gases is described. The values obtained, using nitrogen (N_2) as a standard, are compared with computed values[2] and reasons for discrepancies discussed.

* This research was supported jointly by the National Science Foundation and U. S. Air Force contract between Wright Air Development Center and the University of Nevada.
[1] G. Barnes, Rev. Sci. Instr. **31**, 608 (1960).
[2] G. Barnes (submitted to Rev. Sci. Instr.).

F5. Measurement of Radiative Lifetimes. W. R. BENNETT, JR., A. JAVAN, AND E. A. BALLIK, *Bell Telephone Laboratories*.—Apparatus has been constructed to permit rapid and precise measurement of the lifetimes of excited atomic and molecular states. An electron gun employing an oxide-coated cathode is used as a source of excitation. Periodic millimicrosecond pulses are applied to the grid, and the photon emission rate is counted as a function of time after the grid pulse is turned off. Threshold energy electrons are used. Individual lines are isolated with a grating spectrometer and detected with liquid air-cooled photomultiplier tubes. The detection sensitivity is sufficient to permit measurements over the wavelength range from 1800 to 12 000 A. The data are recorded with a 256-channel pulse-height analyzer used in conjunction with a pulse time-to-height converter. The over-all time resolution is about 1 mμsec. For realistic counting rates, the detection scheme is effectively sensitive in all counting channels simultaneously. Hence the method is both enormously faster and less sensitive to drift than the single-channel delayed-coincidence method used by Heron, McWhirter, and Rhoderick.[1] Preliminary measurements have been made on several neon levels suitable for achieving a population inversion. Several other atoms are being studied.

[1] Heron, McWhirter, and Rhoderick, Proc. Roy. Soc. (London) **A234**, 565 (1956).

F6. Optical Constants of Germanium in the Region 0–27 ev. OM P. RUSTGI, J. S. NODVIK, AND G. L. WEISSLER, *University of Southern California*.—The reflectivity R and transmissivity T have been measured for Ge at 300°K—over the range 7.6 to 18 ev in the case of the reflectivity and 14 to 27 ev in the case of the transmissivity. The transmissivity was obtained for a film of Ge, 800 A thick, which was evaporated on a glass slide coated with sodium salicylate. Onset of transmission occurs near 16 ev, T rising from a value of 0.33% at 16.6 ev to a value of 4.4% at 27 ev. The reflectivity data near normal incidence, combined with those of Philipp and Taft at lower energies, were used in the Kramers-Krönig dispersion relation for $\ln r + i\theta$ to evaluate the real and imaginary parts of the refractive index $n - ik$ over the range 0 to 18 ev. For energies less than 10 ev, the values of n and k thus obtained were not significantly different from those found in previous analyses which extended over the range 0 to 10 ev. With reference to the higher energy region, n rises from a minimum of about 0.8 near 7.5 ev to a flat maximum of 1.13 near 13 ev, and then slowly approaches unity, while k decreases uniformly from a value of 1.0 near 8.5 ev to a value of 0.2 at 18 ev.

F7. Absorption, Ionization, and Ion Fragmentation Cross Sections of Hydrocarbon Vapors for Vacuum Ultraviolet Radiation.* RICHARD SCHOEN, *University of Southern California*.—The ionization and absorption cross sections of the vapors ethane, propane, *n*-butane, *n*-pentane, ethylene, propylene, cis-butane 2, 1, 3-butadiene, and cyclopropane were studied with an ion chamber-photomultiplier system, using radiation in the energy range 9 to 25 ev from a Seya-type vacuum monochromator. When plotted against energy, a typical cross-section curve rose smoothly and monotonically with increasing energy to a single maximum, then fell somewhat more slowly than it rose. Characteristically, the maxima of the ionization and absorption cross sections lay between 14 and 18 ev. It was found that a rough estimate of the maximum absorption cross section of a normal alkane could be made by multiplying the number of bonding electrons in the molecule by 5×10^{-18} cm². This estimate was applicable to propylene, cis-butane 2, and 1,3-butadiene if certain π electrons were ignored. Some ion-molecule reactions were observed.

* Supported by the Geophysics Research Directorate of the Air Force Cambridge Research Center, Air Research and Development Command.

F8. Absorption Cross Section of Sodium Vapor between 1800 A and 1100 A.* R. D. HUDSON, *University of Southern California*.—The continuous absorption of radiation in sodium vapor has been measured from 1800 A to 1100 A. Ditchburn, Jutsum, and Marr[1] have published values of the atomic cross section for wavelengths from the series limit at 2410 A to 1600 A, and the two sets of results agree, within experimental error. Below 1600 A the atomic absorption cross section was found to rise sharply to a peak of 4×10^{-19} cm² at 1400 A and then drop quickly to below 1×10^{-20} cm² at 1100 A. The total oscillator strength of the continuum from the series limit to 1100 A was calculated to be 0.008.

* This work has been in part sponsored by the Geophysics Research Directorate of the Air Force Cambridge Research Center, Air Research and Development Command.
[1] R. W. Ditchburn, P. J. Jutsum, and G. V. Marr, Proc. Roy. Soc. (London) **A219**, 89 (1953).

F9. Viscosity of Dusty Gases. WAYNE T. SPROULL, *Joy Mfg. Co.*—Earlier experiments[1] have been supplemented by tests using a different type of viscosimeter having a vertical sensing cylinder within a coaxial rotating cylinder. As before, the viscosity of room-temperature air was found to decrease about 40% (from about 180 to about 110 micropoises) when limestone dust was suspended in it at a concentration of about 250 g per cubic meter. The reduction was also about 40% for talc dust in the same concentration, despite its lower density and finer particles (99% by weight smaller than 10-μ diameter, compared to 40% for the rock dust). From the observed decrease in viscosity, one may apply kinetic gas theory to calculate that the effective diameter of the dust particles must be larger than their actual diameter by a factor of ten or more. This indicates that each particle is surrounded by a gaseous boundary layer having a thickness comparable to that calculated by other methods.[2]

[1] W. T. Sproull, Bull. Am. Phys. Soc. Ser. II, 3, 411 (1958).
[2] For example, Ewald, Poschl, and Prandtl, *Physics of Solids and Fluids*, 2nd ed., p. 248; H. Schlichting, *Boundary Layer Theory* (Pergamon Press, New York), p. 85.

FRIDAY MORNING AT 10:00

Wheeler Auditorium

(G. F. CHEW presiding)

Invited Papers on Theoretical Nuclear Physics

G1. On Symmetries Shared by Strong and Weak Intractions. A. PAIS, *Institute for Advanced Studies.* (30 min.)

G2. On the Currents in the Weak Interactions. M. GELL-MANN, *California Institute of Technology.* (30 min.)

G3. Prospects for Muon Physics. STEVEN WEINBERG, *University of California and Lawrence Radiation Laboratory, Berkeley.* (30 min.)

FRIDAY MORNING AT 9:30

310 Le Conte Hall

(W. D. KNIGHT presiding)

Magnetic Resonance

Invited Paper

H1. Status of and Recent Development in Maser Research. CHARLES H. TOWNES, *Institute for Defense Analyses* (on leave from Columbia University). (45 min.)

Contributed Papers

H2. Low-Temperature Magneto-Optical and Microwave-Optical Experiments on "*F*" Centers in KCl. IRWIN WIEDER AND JAMES S. HYDE, *Varian Associates.*—The question has arisen as to whether optical selection rules between Zeeman levels of isolated atoms can be extended to atoms whose energy levels are broadened by interactions in a solid.[1,2] In the absence of a detailed theoretical model the question was investigated experimentally using "*F*" centers in KCl. At 2°K in a magnetic field of 2000 gauss there was no detectable difference between the absorption of right and left circularly polarized "*F*" light traveling along the magnetic field with the field on or off. Experiments at 4°K showed pronounced optical effects on the ground magnetic resonance, but in every case the effects could be attributed to lattice heating which changed the dispersion resonance shape under rapid passage conditions[3] by decreasing T_1. Again there was no detectable difference between effects by right or left circularly polarized light. These experiments suggest that conventional optical pumping of ground sublevels will not be possible by simple absorption to broad excited states in solids.

[1] I. Wieder, Westinghouse Quarterly Rept. #4, W.A.D.C. AF33(616)5258 (February, 1958).
[2] J. Lambe and J. Baker, *Proceedings Quantum Electronics Symposium* (Columbia University Press, New York, 1960).
[3] J. S. Hyde, EPR at Work #20, Varian Associates, Palo Alto, California.

H3. Nuclear Spin-Lattice Relaxation Mechanisms for D in KD_2PO_4.* V. HUGO SCHMIDT, HENRY B. SILSBEE, AND EDWIN A. UEHLING, *University of Washington.*—The individual $\Delta m=1$ (p_1) and $\Delta m=2$ (p_2) nuclear spin-lattice relaxation transition probabilities for the deuteron in a KD_2PO_4 single crystal were measured as a function of temperature and crystal orientation, and the combined probability $T_1^{-1}=P_1+2P_2$ was measured as a function of temperature and magnetic field. Above the ferroelectric Curie point T_c, relaxation is due chiefly to time variations of the electric field gradient (efg) induced by two kinds of deuteron motion. The motion most effective above room temperature is the jump motion between hydrogen bonds; P_1 and P_2 calculated from the known jump time[1] and the known efg tensor at the two deuteron sites[2] are proportional to $H_0^{-2}\exp(-0.582\text{ ev}/kT)$, in good agreement with experiment. From room temperature down to T_c, deuteron jumps along the hydrogen bond dominate the relaxation process; P_1 and P_2 are proportional to $H_0^6\exp(+0.078\text{ ev}/kT)$. Differences in the efg tensor consistent with crystal symmetry give the observed angular dependences of P_1 and P_2. Below T_c there is a small transition probability consistent with spin diffusion to paramagnetic impurities.

* Supported by the U. S. Air Force Office of Scientific Research.
[1] V. Hugo Schmidt and Edwin A. Uehling, Bull. Am. Phys. Soc. Ser. II, 4, 462 (1959).
[2] John L. Bjorkstam and Edwin A. Uehling, Phys. Rev. 114, 961 (1959).

H4. Nuclear Spin-Lattice Relaxation by Spin Diffusion to Paramagnetic Ions in KH_2AsO_4.* ERIC D. JONES, HENRY B. SILSBEE, AND EDWIN A. UEHLING, *University of Washington.*—The proton relaxation time T_1 has been measured in the temperature and frequency ranges of 225°K to 300°K and 7.5 Mc/sec to 20 Mc/sec and the results compared with different forms of the spin diffusion theory as discussed most recently by Blumberg.[1] We interpret the strong frequency and temperature dependences which we observe in this crystal as evidence that the relaxation is electron rather than diffusion limited. Typical values of T_1 at 300°K are 67 sec and 19 sec at 20 Mc/sec and 7.5 Mc/sec, respectively, and at 250°K, 87 sec at 20 Mc/sec. The data can be fitted to the spin diffusion theory by taking the paramagnetic ion density $N=7\times10^{15}$ cm^{-3}, the electron relaxation time $\tau=2\times10^{-8}$ sec at 300°K with a T^{-2} dependence, and Blumberg's barrier parameter equal to the lattice constant. N and τ are consistent with the intensity and line widths of EPR measurements.[2] By using the numbers given, Khutsishvili's distance parameter is estimated and found to be consistent with the assumption of electron-limited relaxation.

* Supported by the U. S. Air Force Office of Scientific Research.
[1] W. E. Blumberg, Phys. Rev. 119, 79 (196).
[2] We are grateful to Dr. James S. Hyde of Varian Associates for these measurements.

H5. Interruption of Nuclear Spin Diffusion.* W. H. TANTTILA AND D. A. JENNINGS, *University of Colorado.*—Experimental results are shown in which the nuclear spin diffusion responsible for nuclear relaxation at low temperature, under certain circumstances, can be interrupted by introducing strains into crystals either by the paramagnetic impurity introduced into the crystal or by surface strains made to be significant by grinding the sample to a powder. Nuclei with large quadrupole moments, such as iodine, have their spin diffusion strongly interrupted whereas nuclei with no quadrupole moment, such as fluorine, show no effect of strains on the spin diffusion. The interpretations are made from measured values of the spin-latice relaxation time at liquid helium temperature.

* This research was supported by a grant from the National Science Foundation and also, in part, by the U. S. Air Force under contract monitored by the AF Office of Scientific Research of the Air Research and Development Command. An equipment grant from the University of Colorado Development Fund was used to help purchase a magnet.

H6. Nuclear Spin-Lattice Relaxation Time (T_1) in KBr, KI, and NaI:Tl. W. GILBERT CLARK, *Cornell University.*—T_1 for Br^{79} and Br^{81} in KBr, I^{127} in KI, and Na^{23} and I^{127} in NaI:Tl has been measured in single crystals from 77°K to near the melting point of each substance. The measurements fit into two categories: (a) a temperature range (below 550°K for NaI:Tl and KBr, below 900°K for KI) which, except for Na^{23} near 77°K, yields T_1 measurements intrinsic to the material and whose temperature dependence is in substantial agreement with the Van Kranendonk two-phonon process and (b) a high-temperature range where T_1 measurements can depend on the particular sample used and the dominant T_1 mechanism is diffusion motional relaxation via quadrupolar coupling. At 300°K, T_1 for I^{127} in KI is 0.0156±0.0005 sec, I^{127} in NaI:Tl is 0.0102±0.0003 sec, Na^{23} in NaI:Tl is 8.46±0.43 sec, Br^{79} in KBr is 0.0725±0.0025 sec, and Br^{81} in KBr is 0.104±0.003 sec. Above 175°K, measurements in the temperature range for intrinsic values of T_1 are fitted by a power law dependence on absolute temperature, which is $T^{1.88\pm0.07}$ for I^{127} in KI, $T^{1.91\pm0.03}$ for Br^{79} and Br^{81} in KBr, $T^{1.94\pm0.07}$ for I^{127} in NaI:Tl, and $T^{1.78\pm0.13}$ for Na^{23} in NaI:Tl. No evidence for the Khutsishvili four-phonon T_1 mechanism is observed.

H7. Nuclear Double Resonance Spectroscopy.* S. HARTMANN AND E. L. HAHN, *University of California, Berkeley.*—A transient double spin resonance method is applied, which improves the previous[1] sensitivity for rare spin detection by a factor T_1/T_2. Directly following an intense 90° rf pulse field H_1 acting on a set of A indicator nuclei, the rf phase is suddenly shifted by 90°. The A nuclear magnetization then locks in the direction of H_1 for a time T_1. A second set of B nuclei interacts with the A system by applying a continuous rf field at the B resonance frequency with such an rf amplitude that the A and B systems precess about their respective rf fields at the same frequency. A dipole-dipole A-B coupling then occurs for a time T_1, after which H_1 is turned off, and the free precession A signal is observed to be degraded in amplitude. The locked A system is cumulatively depolarized if the B spins are saturated by means of periodic 180° phase shifts applied to the B resonance rf field. Experimental results will be discussed.

* Supported in part by the Office of Naval Research.
[1] M. Emshwiller, E. L. Hahn, and D. Kaplan, Phys. Rev. 118, 414 (1960).

H8. Proton Magnetic Resonance Study of Polycrystalline $HCrO_2$. J. A. IBERS, C. H. HOLM, AND C. R. ADAMS, *Shell Development Company, Emeryville.*—A proton magnetic resonance study of polycrystalline $HCrO_2$ as a function of magnetic field and temperature is presented. $HCrO_2$ is paramagnetic, and electron paramagnetic dipole as well as nuclear dipole effects lead to line broadening. The lines are asymmetric, and over the range of field $470\leq H_0\leq9400$ gauss and temperature $77°\leq T\leq294°K$ the asymmetry increases with increasing H_0 and decreasing T. An isotropic resonance shift of 0.017% to lower applied fields indicates a weak isotropic hyperfine contact interaction. The general theory of resonance shifts is used to derive a general expression for the second moment M_{2p} of a polycrystalline paramagnetic sample and is specialized to $HCrO_2$. The theory predicts a linear dependence of M_{2p} on $[H_0/(T+\theta)]^2$, where θ is the experimentally determined Curie-Weiss constant. The experimental second moment $M_{2p'}$ conforms to the relation $M_{2p'}=(3.96\pm0.06)+(0.084\pm0.002)(H_0/(T+276))^2$ in agreement with theory. Hence the electron paramagnetic effects (slope) can be separated from the nuclear effects (intercept). The paramagnetic dipole effects provide some information on the particle shapes. The nuclear dipole effects provide some information on the motions of the hydrogen nuclei, but the symmetry of the O-H-O bond in $HCrO_2$ remains in doubt.

H9. Paramagnetic Broadening of Nuclear Spin-Resonance Lines.* P. A. BENDER† AND W. H. TANTTILA, *University of Colorado.*—Existing theories of nuclear spin-lattice relaxation in diamagnetic solids assume that paramagnetic impurities play the major role in allowing the nuclear spin system to come into equilibrium with the lattice. These theories assume that the paramagnetic moment of the impurity is reorienting rapidly at all temperatures. If it is flipping rapidly enough, the neighboring nuclei see a time averaged magnetic moment, given by the Curie law. If this is so, the nuclear magnetic resonance line should broaden inversely with the temperature. We have tested this assumption by measuring the fluorine nuclear spin resonance line widths from 4°K to 300°K in KF with $MnCl_2$ as the impurity. We found that from room temperature to about 120°K the line widths do follow a Curie law, but below this temperature the lines broaden rather suddenly. We suggest that at about 120°K the paramagnetic flip rate has decreased such that the fluorine nuclei see the static moment of the paramagnetic ion. The spin-lattice relaxation time for the paramagnetic ion at this temperature can be estimated.

* Supported in part by the National Science Foundation.
† Now at Washington State University.

H10. Nuclear Resonance Thermometry and Relaxation Below 1°K.* R. WALSTEDT AND E. L. HAHN, *University of California, Berkeley,* AND C. FROIDEVAUX, *Clarendon Laboratory, Oxford.*—A pulsed nuclear free-precession technique has

been applied to the measurement of temperatures below 1°K. The nuclear magnetization M_0 is a measure of the spin temperature $T_s \propto 1/M_0$, and the spin-lattice relaxation time T_1 gives a measure of the lattice temperature T_l from the Korringa relation T_1T_l=const. M_0 is rotated through small angles θ by the action of nonadiabatic dc field pulses, and precesses freely about low fields H_0. Measurements of Cu, Na, Al, and Pt have been made in the 0.02°K to 1°K range. The nuclear cooling results of Kurti and collaborators are verified.[1] T_1T_l in Pt^{195} yields 6.9×10^{-2} sec°K at $T_l \cong 0.02$°K.

* Supported in part by the Office of Naval Research.
[1] N. Kurti and M. V. Hobden, Phil. Mag. [4] 45, 1092 (1959).

FRIDAY MORNING AT 10:00

1 Le Conte Hall

(H. V. NEHER presiding)

General Physics. II

I1. Design of an Experiment to Measure the Dispersive Properties of Space for Electromagnetic Radiation.* S. D. SOFTKY† AND R. K. SQUIRE, *Lawrence Radiation Laboratory, Livermore.*—The theory of special relativity postulates that all electromagnetic radiation propagates with the same velocity c in free space. Measurements of c for different frequencies of radiation (radio waves, light, and ratio of esu to emu) have not demonstrated that c is independent of frequency. Astronomical tests of the invariability of c with frequency have been done only for optical frequencies. In view of the importance of c in many physical theories, it is thought that an accurate comparison for radio, optical, x-ray, and γ-ray frequencies would be worthwhile. The design of an experiment to obtain the above comparison for a frequency range whose extremes differ by a factor of 10^{11} will be presented. The experiment will consist of detonating a nuclear explosive at a distance of the order of 10^6 miles from the earth and noting the arrival times of the different types of radiation at detectors above the atmosphere. The nature of the detectors and necessary instrumentation will be described and an estimate given of the precision with which any variation in c with frequency could be measured.

* Work done under the auspices of the U. S. Atomic Energy Commission.
† Of Stanford Research Institute. Consultant to the Lawrence Radiation Laboratory.

I2. Evidence for a Ring Current. PAUL J. KELLOGG AND JOHN R. WINCKLER, *University of Minnesota.*—At times during solar proton events, protons having energies down to 75 Mev and probably lower reach Minneapolis, where the cutoff is normally 300–400 Mev. The arrival of such low-energy protons in full intensity coincides in time with the beginning of the main phase of a magnetic storm.[1] These observations can be understood if one postulates a ring current and/or a ring distribution of magnetization around the earth at these times. By combining cosmic ray and magnetic measurements, it can be shown that the ring must have a magnetic moment greater than the earth's and must have a major radius of 7–10 earth radii, or possibly more. The flux of trapped particles required to give such a ring is quite large, as upper limits on their energy are given by satellite-borne radiation counters. These measurements therefore provide additional evidence[2] that the earth's field is a good trap out to 10 earth radii and that a considerable part of the total energy in the Van Allen zones is trapped in this distant region.

[1] P. D. Bhavsar and J. R. Winckler (to be published).
[2] Smith, Coleman, Judge, and Sonnett, J. Geophys. Research 65, 1858 (1960).

I3. Balloon Observations of Auroral Zone X-Rays.* R. R. BROWN, *University of California, Berkeley.*—A series of fourteen balloon flights launched from the vicinity of College, Alaska, during June and July, 1960, show that auroral zone x rays are detectable with Geiger counters approximately 10% of the time at pressure altitudes in the range 10–20 mb. An analysis of the results of 141 hr of routine observation at these altitudes indicates that a daily flux of 6×10^{10} electrons/cm^2 with energies greater than 50 kev strike the top of the atmosphere. Individual bursts of electrons which gave rise to x rays at balloon altitude produced ionospheric disturbances. The results obtained from one flight, launched specifically to investigate the electron flux under disturbed geophysical conditions, indicate that the average electron flux on a disturbed day can exceed the daily flux by more than a factor of 20.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

I4. Breakdown in Electron Sheath.* C. W. HARTMAN, M. CHAMRAN, AND D. H. SLOAN, *University of California.*—Crossed-field drifting electron slipping stream oscillation turbulence increases with beam or sheath thickness d and with constraining B. A constant maximum Bd value fixes turbulent amplitudes in which multipactors grow into breakdown with a given secondary emission δ and gas evolution from cathode. An aluminum cathode with deep slots filled with air plasma, sheath voltage E=10 kv, d=1 cm, had breakdown at particle density above $n=10^{13}$ independent of B in the range 0.7 to 2.5 kg. In other tubes without cathode slots breakdown is independent of n over same B range, varying d; Bd=const. Electric ion pumping holds positive ions, B holds electrons, and unrestrained negative ion current is large. Cycloidal drift electrons obey the diffusion law, crossing sheath with random collision time equal to buildup time of slipping stream oscillations in vacuum, changing with gas collision time when gas is added. Current squared varies with n. Maximum n varies with current obtainable at given E and B. Electrons traveling from end to end of the cathode along B lines that pass close to the anode exchange energy with turbulent stream; some strike the cathode end with over 1 kev at B near breakdown.

* Work supported by the U. S. Air Force Cambridge Research Laboratory, Air Research and Development Command.

I5. Nature of Coordinate Transformations in Quantized General Relativity.* JOHN G. FLETCHER,† *University of California, Berkeley.*—It is argued that in a quantized theory of general relativity the functions describing coordinate transformations must be operators and not c numbers. The argument is based upon the assumption that quantum-mechanical commutators have properties similar to those of Poisson Brackets and upon the fact that the Poisson Brackets in general relativity possess a gauge which can be derived from the gauge (general covariance) of the field variables themselves only when it is assumed that the Poisson Brackets of field variables with the functions describing coordinate transformations do not vanish. It is further argued that, neverthe-

less, the coordinates themselves may not need to be treated as operators.

* Work supporrted in part by the Grumman Aircraft Engineering Corporation.
† Fellow of the Miller Institute for Basic Research in Science.

I6. Uniqueness of Lorentz-Covariant Gravitational Field Equations. JOHN M. CORNWALL,* *University of California, Berkeley.*—We have investigated to what extent the assumptions of special relativity and that the energy of the gravitational field occurs as a source of the gravitational field exactly as other external fields, lead to a unique theory of gravitation. Beginning with an arbitrary Lagrangian containing only first derivatives of the field variables, this feedback requirement that the canonical stress-energy tensor be a "source" term for the Euler-Lagrange equations can be satisfied by two different Lagrangians. Finally the requirement that Newton's gravitational theory be obtained in the limit singles out uniquely the Einstein generally covariant theory. The relation of this work to that of Gupta and Kraichnan will be discussed.

* National Science Foundation Predoctoral Fellow, 1960–61.

I7. Interaction of Vibration and Rotation in Polyatomic Molecules.* DUDLEY R. HERSCHBACH, *University of California, Berkeley,* AND VICTOR W. LAURIE, *Stanford University.*—Spectroscopic experiments yield effective moments of inertia contaminated by vibration-rotation interactions. For polyatomic molecules, the corrections rarely can be determined experimentally, and a molecular structure derived from the effective moments has no simple relation either to the equilibrium structure or to the average structure determined by diffraction methods. Previous theoretical treatments of vibration-rotation interaction have provided a perturbation expansion about the equilibrium configuration. However, the most important correction terms involve the anharmonic part of the vibrational potential, which seldom is known with sufficient accuracy to permit useful calculations. A more general treatment is given in which the perturbation expansion may be referred to any arbitrarily chosen, fixed configuration of the atoms. From this it is found that to a practical approximation the entire effect of anharmonicity is absorbed in displacing the average from the equilibrium configuration. Hence only the harmonic part of the vibrational potential is needed to correct observed effective moments of inertia to those for the average structure of a molecule.

* Supported by the Alfred P. Sloan Foundation, the U. S. Atomic Energy Commission, and the National Science Foundation.

I8. Determination of Molecular Structure from Spectroscopic Data.* VICTOR W. LAURIE, *Stanford University,* AND DUDLEY R. HERSCHBACH, *University of California, Berkeley.*—From known harmonic potential constants and observed moments of inertia, calculations have been made of the moments of inertia for the average configuration of a number of molecules. From these moments, the structural parameters corresponding to the average molecular configuration have been obtained. These parameters are free from the ambiguities of "quantum defects" and related inconsistencies found in "effective" or "substitution" parameters. They have a clearly defined physical meaning and are directly comparable with diffraction results. Examples are CH_4 where $\langle r_{CH}\rangle = 1.100$ A and CD_4 where $\langle r_{CD}\rangle = 1.097$ A. These differences between H and D parameters are typical. Much smaller but significant differences for isotopes of heavier atoms also are found. The effect of these variations upon structure determinations will be discussed.

* Supported by the National Science Foundation, the Alfred P. Sloan Foundation, and the U. S. Atomic Energy Commission.

I9. 200-kgauss Pulsed Magnets.* R. L. KUSKOWSKI, T. B. NOVEY, AND S. D. WARSHAW, *Argonne National Laboratory.*—A compact stable design for a pulsed magnet normally operated at 200 kgauss in a volume of 2-cm diameter and 7-cm length has been constructed and tested. The magnet coil is a 48-turn helix made from edge-wound silver tape 0.05 in. thick and 0.4 in. wide or machined to these dimensions from a hardened beryllium-copper bar. The coil is insulated between turns with epoxy impregnated fiber glass 0.010 in. thick, radially strengthened by winding with continuous glass roving impregnated with epoxy resin and axially clamped with stainless steel end plates. The assembled unit is 3½ in. in diameter and 3½ in. long. The inside surface of the windings is electropolished to inhibit arcing and cooled with silicone oil at −60°C. The 24 000-amp half-cycle ½-msec current pulse is obtained by the discharge of energy stored in 900 μf at 5 kv through four parallel 2-in. ignitrons. About half of the energy of the bank is dissipated in the coil during the pulse; the remainder is returned to the storage bank for the succeeding pulse. The system is automatically cycled at periods down to 5 sec. Several coils have been life-tested to 7000–12 000 pulses before failure. A total of 28 coils have been assembled and tested for 500 pulses. In actual use they will be replaced after an expected safe operating time of 5000 pulses.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

I10. Rules Concerning Magnitudes of the Chief Isotopes. NICHOLAS EFREMOV, *New York.*—Mattauch's rules concerning isotopes, which were established on an empirical basis, must be broadened. As a first step in this direction we introduce "mass difference rules of isotopes." In relation to the chief isotopes these rules are: 1. The mass difference magnitudes (−3, −1, 1, 2, 3, 5, 7, 9) between the atomic weights of the chief isotopes of successive series of natural elements (e.g., H- He- Li, etc.) cannot be more than 9 or less than −3. The numbers 1, 5, and 3 are the prevailing mass difference numbers. 2. The algebraic sums (x) of the mass difference numbers of the chief isotopes of the first eight elements belonging to the He, Ne, A, Kr, and Xe periods are calculated by the simple formula $X=[(a\times 8)-1]=15$ and are equal to 15. In this formula a is the "average magnitude" of the mass difference (which always equals 2) and 8 is the number of elements taken. For example,

	Xe period							
Elements	Xe	Cs	Ba	La	Ce	Pr	Nd	Pm
Chief isotopes	132	133	138	139	140	141	144	147
Mass differences		1	5	1	1	1	3	3
Sum of mass differences		1	+ 5	+ 1	+ 1	+ 1	+ 3	+ 3 = 15

FRIDAY MORNING AT 10:00

4 Le Conte Hall

(G. T. SEABORG presiding)

Low-Energy Nuclear Physics. II

J1. Neutron Yields from Thin Targets Bombarded by 31-Mev Protons.* T. M. HENDERSON, PAUL S. LEWIS, AND CHARLES N. WADDELL, *University of Southern California.*—The USC 31-Mev proton linear accelerator is being used to study the neutron yields from thin targets bombarded by protons. The neutrons are detected in a moderated array of

BF_3 counters enclosed in a 3-ft thick concrete shield. The efficiency of the neutron detection system is determined with a Ra-α-Be neutron source. Neutron yields have been measured for 20 elements of natural isotropic abundance. Yields from enriched targets of Cu and Ni have been measured in order to investigate the discontinuity in yield from thick targets at $Z=30$ observed by Tai *et al.*[1] A comparison will be made to the yields expected from the neutron spectrum and angular distribution measurements of Bostick *et al.*[2]

* Supported by the U. S. Atomic Energy Commission.
[1] Y. K. Tai, G. P. Millburn, S. N. Kaplan, and B. J. Moyer, Phys. Rev. 109, 2086 (1958).
[2] H. A. Bostick, UCRL 8528, and H. E. Adelson, H. A. Bostick, B. J. Moyer, and C. N. Waddell (to be published).

J2. Charged Particle Reaction Cross Sections for 31-Mev Protons.* J. KIRK DICKENS, DAVID HANER, AND CHARLES N. WADDELL, *University of Southern California.*—The angular distributions of charged particles produced in the bombardment of targets by 31-Mev protons are being studied. The particles are detected in a NaI(Tl) crystal and the resulting spectrum analyzed in a 100-channel pulse height analyzer. Subtraction of the elastically scattered contribution from the observed spectrum gives a lower limit to the charged particle reaction cross section. This cross section is combined with the neutron reaction cross sections presented in the previous abstract to obtain a lower limit for the proton total reaction cross section. These results should prove useful in helping to resolve some of the ambiguities in assigning optical model parameters.

* Supported by the U. S. Atomic Energy Commission.

J3. Elastic and Inelastic Scattering Cross Sections of 31-Mev Protons in Ni^{60}.* G. G. GIGAS, S. M. BUNCH, D. W. DEVINS, AND H. H. FORSTER, *University of Southern California.*—The 31-Mev beam of the proton linear accelerator at the University of Southern California has been used to bombard targets of Ni^{60} of $\sim$11.3 mg/cm^2 thickness. The scattered particles passed through $\sim$5 mils of mylar before entering the counter assembly, except for measurements at very low energies where the mylar thickness was reduced to $\frac{1}{2}$ mil. The charged particle detector consisted of a 2-in.$\times\frac{1}{4}$-in. thallium activated NaI crystal, optically coupled to a RCA 6655 A photomultiplier. The energy spectrum of the scattered particles was obtained by means of a 100-channel pulse height analyzer, the resolution of the total assembly being $\sim$2%. Angular distributions of charged particles scattered from Ni^{60} were made at laboratory angles of from 25°–120°. Absolute cross sections were determined for protons scattered elastically from the target, as well as for protons scattered inelastically from the first excited level in Ni^{60} at 1.33 Mev. Thirty-one-Mev proton inelastic and charged particle cross sections were obtained.

* This work was supported by the U. S. Atomic Energy Commission.

J4. Relative Stopping Power of Some Metallic Elements for 28.7-Mev Protons.* G. H. NAKANO AND K. R. MACKENZIE, *University of California, Los Angeles,* AND H. BICHSEL, *University of Southern California.*—The proton beam of the USC Linear Accelerator was used to measure the stopping power relative to aluminum at the mean energy of 28.7 Mev for Be, Ti, V, Co, Ni, Cu, Ag, Ta, Ir, and Au. The experiment was designed to give results accurate to 0.2%. A split beam method was employed in which the beam was first multiply scattered by a mylar foil, and by collimation two identical beams were obtained. This technique permitted the continuous monitoring of beam energy and intensity during the measurement. The relative mass stopping powers thus obtained are, in the order of elements listed: 1.0894, 0.8969, 0.8605, 0.8501, 0.8691, 0.8233, 0.7164, 0.5981, 0.5849, and 0.5838. A plot of the relative stopping power per electron against $\ln Z$ shows deviations from the systematic straight line relationship indicating effects of the atomic shell structure. These results are in agreement with data obtained at lower energies in previous investigations.[1,2]

* Supported by the joint program of the U. S. Atomic Energy Commission and the Office of Naval Research.
[1] V. C. Burkig and K. R. MacKenzie, Phys. Rev. 106, 848 (1957).
[2] M. Bader, R. E. Pixley, F. S. Mozer, and W. Whaling, Phys. Rev. 103, 32 (1956).

J5. Experimental Results with a Lithium Drifted Silicon Diode Radiation Detector.* JACK H. ELLIOTT, *Lawrence Radiation Laboratory, Berkeley* (introduced by B. Harvey).—Lithium diffused into 100 Ω-cm p-type silicon was drifted at 140°C while maintaining bias voltage following the method of E. M. Pell.[1] A depletion layer of 35-mil thickness was produced. Preliminary energy resolution measurements using the Crocker Laboratory 60-in. Cyclotron 48-Mev He^4 ion beam, elastically scattered and degraded to 40 Mev and below, yielded widths measured at half-maximum peak intensity between 3.2 to 4% at a detector bias of only 10 v.

* This research was sponsored by the U. S. Atomic Energy Commission.
[1] E. M. Pell, J. Appl. Phys. 31, 291 (1960).

J6. Table of Asymmetric Rotor Electric-Quadrupole Gamma-Ray Transition Probabilities.* PAUL P. DAY AND CARLOS A. MALLMANN, *Argonne National Laboratory.*—Electric quadrupole reduced gamma-ray transition probabilities between states of an asymmetric rotor have been computed.[1] They are given as a function of the asymmetry parameter $k[k=(2B-A-C)/(A-C)$ where A, B, and C are reciprocal to the three moments of inertia] for values -1.0, -0.95, . . . 1.0 and the ratio of the effective quadrupole moments $r[r=k_2=k_2/\sqrt{2}k_0$ where k_0 and k_2 are ground-state expectation values of $\Sigma(3z_i^2-r_i^2)$ and $\Sigma(x_i^2-y_i^2)$, respectively] for the range -1.5, -1.475, . . . 1.5. These values were computed (to an accuracy of 1 part in 10^4) in order to compare the transition probability predictions of the general asymmetric rotor model[2] of even-nuclei with experimental results.

* Based on work performed under the auspices of the U. S. Atomic Energy Commission.
[1] To be published as ANL-6184.
[2] C. A. Mallmann, International Conference on Nuclear Structure, Kingston, Ontario, Canada (August, 1960) and Nuclear Phys. (submitted for publication).

J7. Energy Levels of Nonaxially Symmetric Even-Even Nuclei with Vibration-Rotation Interaction.* ERNEST D. KLEMA, PAUL P. DAY, AND CARLOS A. MALLMANN, *Argonne National Laboratory.*—Davydov and Chaban[1] have extended the work of Davydov and Filippov on the collective excited states of nonaxially symmetric even-even nuclei by including the beta-vibration-rotation interaction in an exact manner. We have solved Eq. 2.12 of their paper, using a digital computer, for 34 energy levels. The results[2] for the energies of the states (accurate to 1 part in 10^4) are given in terms of the "nonadiabaticity" parameter μ (1.0, 0.90, $\cdots$0.4, 0.35$\cdots$0.1) and the "nonaxiality" parameter γ (30°, 25°, 20°, 15°, 12°, 10°, and 8°). The calculated energies have been compared with experimental data for nuclei with $40\leq A\leq 250$. Where possible, comparison has been made also with the correlation of experimental data by means of the perturbation approach of Mallmann and Kerman and of the Bohr-Mottelson model.

* Based on work performed under the auspices of the U. S. Atomic Energy Commission.
[1] A. J. Davydov and A. A. Chaban, Nuclear Phys. (to be published).
[2] To be published as ANL report #6220.

J8. Comparison of Two Models for the Many Fermion System.* E. M. HENLEY AND L. WILETS, *University of Washington.*—A critical comparison is made between the Overhauser[1] and Bardeen-Cooper-Schrieffer trial wave functions for attractive fermion systems. First, a nonseparable

Gaussian potential is considered in one dimension. The BCS equations are solved exactly in strong and weak coupling and approximately for intermediate values. The Overhauser ground state energy[2] is always higher. Second, in any number of dimensions, a constant thin shell interaction yields exact Overhauser ground state energies always higher than those of BCS. Furthermore,[3] a finite interaction strength is required in two or more dimensions before the Overhauser wave function gives any improvement over plane waves. Finally, for the one-dimensional shell interaction, a BCS function constructed of time-reversed Overhauser pairs is inferior to one composed of plane wave pairs. Thus BCS correlations appear to destroy Overhauser correlations.

* Supported in part by the U. S. Atomic Energy Commission.
[1] A. W. Overhauser, Phys. Rev. Letters **4**, 415 (1960).
[2] E. M. Henley and Th. W. Ruijgrok, Ann. Phys. (to be published).
[3] W. Kohn and S. J. Nettel, Phys. Rev. Letters **5**, 8 (1960).

J9. Vibrational States of Systems of Fermions and Single-Particle Excitations.* J. SAWICKI, *University of California, Berkeley* (introduced by A. E. Glassgold).—The system of nonlinear equations for the components of the single-particle density matrix operator is discussed for both infinite and finite systems of fermions interacting through a two-body "residual" interaction. The Hartree-Fock factorization and linearization of that system of equations for the density fluctuations can be performed. Hartree-Fock exchange terms and, particularly, deviations from the random phase approximation are discussed. The importance of these deviations is illustrated by the example of the quadrupole vibrations of a closed spherical nuclear subshell. An apparent ambiguity in the linearization procedure is discussed, and the importance of the nonlinearity of equations is stressed.

* This work was supported in part by the U. S. Atomic Energy Commission and the Office of Naval Research.

J10. Equilibrium Configurations and Energetics of Uniform Rotating Charged Liquid Drops.* JOHN R. HISKES, *Lawrence Radiation Laboratory, Livermore.*—Hilac bombardments can lead to the formation of compound systems which contain orbital angular momenta in excess of 100 units of $\hbar$. The liquid drop model is extended to include a rotational energy term to study the effects of these large rotational forces on the fissionability of the system. Following Pik-Pichak,[1] an analytic treatment is given based on a parametric expansion for small ellipsoidal distortions about a sphere; these calculations yield the ground state and saddle shape configurations leading to fission as functions of charge and angular momentum of the drop. A variation-iteration method for generating the configurations of equilibrium is described. The method is applied to axially symmetric drops over the range $0 \leq x \leq 1$ and $0 \leq y \leq 0.5$, where x is the ratio of the Coulomb energy to twice the surface energy for a sphere and y is the ratio of the rotational energy to the surface energy for a sphere. The energetics are calculated. The fission thresholds are calculated in the range of applicability of the parametric expansion.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] G. A. Pik-Pichak, Soviet Phys.—JETP **7**, 238 (1958).

J11. Phenomenological Description of p-p Scattering.* HENRY P. STAPP,† MICHAEL J. MORAVCSIK, AND H. PIERRE NOYES, *Lawrence Radiation Laboratory, Livermore.*—Work is continuing on our program to determine the energy dependence of proton-proton phase shifts from experimental data between 10 and 400 Mev. The high angular momentum states are given by the one-pion exchange contribution. We are now investigating the range of allowable solutions of the SYM 1 type[1] and the possibility of other good but basically different solutions. The dependence of the fits on the pion-nucleon coupling constant is also being studied. Results will be reported at the meeting.

* Work done under the auspices of the U. S. Atomic Energy Commission.
† Lawrence Radiation Laboratory, Berkeley.
[1] H. P. Stapp, T. J. Ypsilantis, and N. Metropolis, Phys. Rev. **105**, 302 (1957).

FRIDAY AFTERNOON AT 2:00

1 Le Conte Hall

(A. E. GLASSGOLD presiding)

Invited Papers on Helium and Phonon Physics

K1. Theory of Liquid He³. K. A. BRUECKNER, *University of California, La Jolla.* (30 min.)
K2. Nature of the λ-Transition in Liquid He⁴. W. M. FAIRBANK, *Stanford University.* (30 min.)
K3. Ultra-High-Frequency Sound Waves in Solids. H. E. BÖMMEL, *Bell Telephone Laboratories.* (30 min.)
K4. Transmitted Phonon Drag in Silicon. KURT HUBNER, *Shockley Transistor.* (30 min.)

FRIDAY AFTERNOON AT 1:30

312 Le Conte Hall

(H. A. SHUGART presiding)

Molecular Beam and Gas Ion Physics

Invited Paper

L1. Atomic Beam Measurements on the Low-Lying Electronic States of the Lanthanide and Actinide Elements. RICHARD MARRUS, *University of California and Lawrence Radiation Laboratory, Berkeley.* (30 min.)

Contributed Papers

L2. Reactive Scattering in Crossed Molecular Beams.* GEORGE H. KWEI, JAMES A. NORRIS, AND DUDLEY R. HERSCHBACH, *University of California, Berkeley.*—Angular distributions of reactively scattered KI have been measured at the intersection of a K atom beam with beams of CH_3I and C_2H_5I. The beams are formed by thermal effusion from ovens mounted on a turntable which is rotated to sweep the angular distribution past surface ionization detectors. The KI distributions show broad peaks far from the K beam (at 90–100° for CH_3I, 100–110° for C_2H_5I). The peaks have more than ten times the intensity of the elastic scattering in this region and become more prominent with increasing beam temperatures. An analysis which relies only on the conservation laws of energy and momentum is given. With this several features of the reactive scattering can be inferred from these experiments: (1) as seen by an observer riding on the center of mass, the angular distribution of products is quite anisotropic; (2) in the scattering which contributes to the wide-angle peaks, the KI recoils backwards and the CH_3 or C_2H_5 forwards with respect to the incoming K beam, and (3) most of the energy of reaction goes into internal excitation of the products.

* Supported by the U. S. Atomic Energy Commission and the Alfred P. Sloan Foundation.

L3. Electron Attachment in NO_2.* V. A. J. VAN LINT, R. H. HAMMOND, J. PAREZ, AND E. G. WIKNER, *General Atomic.*†—Electron attachment in NO_2 and NO_2 diluted with A or He has been studied by observing the electron density in a gas sample subjected to a short pulse of ionizing radiation. The ionization was produced by a 5-μsec pulse of 25-Mev electrons from the General Atomic linear accelerator. The electron density during and after the radiation pulse was observed by measuring the attenuation and phase shift of an X-band microwave propagated through the ionized gas. In NO_2 electron-density relaxation times of approximately 2 μsec were observed at a pressure of 1.5 mm Hg. The relaxation time decreased with increasing pressure, but not in the manner to be expected from either a simple two-body or three-body attachment process. Moreover, the electrons observed accounted for less than 5% of the electrons ionized. These experiments, and others with mixtures of A or He and NO_2 indicate that the attachment cross section in NO_2 is very large and that not all the electrons are thermalized before attaching.

* Sponsored by U. S. Air Force Special Weapons Center contract.
† John Jay Hopkins Laboratory for Pure and Applied Science, General Atomic, Division of General Dynamics Corporation, San Diego, California.

L4. Low-Energy Electron Scattering from Atomic Oxygen.* R. H. NEYNABER, E. W. ROTHE, L. L. MARINO, AND S. M. TRUJILLO, *Convair—San Diego Division.*—The total cross section for the scattering of electrons by atomic oxygen has been measured as a function of electron energy from 2.3 to 11.5 ev. The measurement compared the number of electrons scattered from a region defined by the intersection of an electron beam and a modulated molecular oxygen beam with the number scattered when the oxygen beam was partially dissociated. A radio-frequency discharge dissociated about 30% of the molecules. The degree of dissociation was measured with a mass spectrometer. From the data, the ratios of atomic to molecular scattering cross sections were obtained. The absolute atomic values were calculated by multiplying these ratios by the molecular oxygen cross sections of Brüche.[1] These results are compared with five theoretical estimates. Those of Temkin[2] and of Klein and Brueckner[3] are consistent with the data.

* Supported in part by the Advanced Research Projects Agency through the Army Rocket and Guided Missile Agency.
[1] E. Brüche, Ann. Physik **83**, 1065 (1927).
[2] A. Temkin, Phys. Rev. **107**, 1004 (1957).
[3] M. M. Klein and K. A. Brueckner, Phys. Rev. **111**, 1115 (1958).

L5. Electron Scattering from Hydrogen. CHARLES SCHWARTZ, *University of California, Berkeley.*—Large-scale calculations of the elastic scattering of electrons from the hydrogen atom have been undertaken. The Kohn-Hulthen variational principle has been used with trial functions which, in addition to the known asymptotic part, are fashioned after those used so successfully for the bound states by Hylleraas and others. Terms are taken in a systematic way, through seventh powers in the triple power series, and the successively determined phase shifts vary smoothly, allowing reasonable error estimates. It is disappointing that the rate of convergence we find (for *s*-waves only so far) is very slow; nevertheless the values we obtain are thought to be the best available (~1% accuracy).

L6. Forward Momentum Effects in Ion Bombardment. FRED E. HOLMSTROM AND ROBERT D. KNIGHT, *IBM Research Laboratory.*—Ion bombardment of surfaces, at oblique angles of incidence, has been observed to result in an asymmetrical distribution of ejected target material at low ion energy[1] and for one ion-target combination at 9 kev.[2] Further studies of forward momentum effects are being pursued with an ion beam system delivering a current density of 20 ma/cm^2. Results will be reported for He and Ar ion bombardment of Ag targets for ion energies up to 50 kev using radioactive tracer techniques in the experimental analysis.

[1] G. K. Wehner and D. Rosenberg, J. App. Phys. **31**, 177 (1960).
[2] F. Gronlund and W. J. Moore, J. Chem. Phys. **32**, 1540 (1960).

L7. Nuclear Spin of Rb^{88}.* V. J. EHLERS AND H. A. SHUGART, *University of California and Lawrence Radiation Laboratory, Berkeley.*—The atomic-beam magnetic-resonance method has been used to measure the nuclear spin of 17.8-min Rb^{88}. A spin search was conducted at low magnetic field and indicated that the nuclear spin is 2, in agreement with the result deduced from nuclear spectroscopic data.[1] Resonances corresponding to the "flop-in" transition $(5/2,-3/2)\leftrightarrow(5/2,-5/2)$ were observed at higher magnetic fields, confirming the spin assignment. The radioactive isotope was produced from stable rubidium by the reaction $Rb^{87}(n,\gamma)Rb^{88}$ in the General Electric Test Reactor at Vallecitos Atomic Laboratory. Detection of the Rb^{88} was accomplished by collecting the atoms on sulfur-coated buttons and measuring the deposited radioactivity with continuous-flow Geiger counters. The beam intensity was monitored by measuring the amount of stable rubidium impinging on a hot-wire ionization detector.

* Supported in part by the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] M. E. Bunker, L. M. Langer, and R. J. D. Moffat, Phys. Rev. **81**, 30 (1951).

L8. Nuclear Spin of Ag^{113}.* Y. W. CHAN, W. B. EWBANK, W. A. NIERENBERG, AND H. A. SHUGART, *University of California and Lawrence Radiation Laboratory, Berkeley.*—The nuclear spin $I=\frac{1}{2}$ for radioactive Ag^{113}($T_{\frac{1}{2}}=5.3$ hr) has been measured by the atomic-beam magnetic-resonance method. The isotope was produced from natural palladium metal by an (α,p) reaction with 48-Mev α particles from the Crocker 60-in. cyclotron. The Ag^{113} produced in this way is always mixed with 7.5-day Ag^{111}($I=\frac{1}{2}$) which has a hyperfine structure very close to that of Ag^{113}. Therefore, the spin assignment of Ag^{113} could be identified unambiguously only

when the observed resonances of Ag^{111} and Ag^{113} were separated by the atomic-beam apparatus at a magnetic field of over 100 gauss.

* This research work was supported by the Office of Naval Research and the U. S. Atomic Energy Commission.

L9. Nuclear Moments of I^{132}.* M. B. WHITE, S. S. ALPERT, H. L. GARVIN, AND E. LIPWORTH, *Lawrence Radiation Laboratory, Berkeley.*—The magnetic dipole interaction constant a and the electric quadrupole interaction constant b have been measured in 2.3-hr I^{132} ($I=4$) by an atomic beam resonance experiment. The results are $|a|=567.6\pm1.3$ Mc, $|b|=128.2\pm10.3$ Mc with b/a positive. These results when combined with the known values of a, b, μ, and I of stable I^{127} yield the nuclear magnetic moment and nuclear quadrupole moment of I^{132}. We find $|\mu_{132}|=3.084\pm0.007$ nm (diamagnetically corrected) and $|Q|=0.09\pm0.01$ barn, where a small core polarization or Sternheimer correction has been included. The sign of μ is not determined, but μ and Q must have opposite signs. The I^{132} was obtained by a milking process from Te^{132} in an iodine generator supplied by Brookhaven National Laboratory. A total of 16 resonances were observed at magnetic fields ranging from 6.9 to 374.7 gauss. At each field the two flops in resonances $(11/2, -7/2) \leftrightarrow (11/2, -9/2)$ and $(9/2, -5/2) \leftrightarrow (9/2, -3/2)$ were observed. The data were reduced using an IBM 704 digital-computer routine.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

L10. Nuclear Spins of Pm^{149}, Pm^{151}, and Tb^{160}.* A. CABEZAS, I. LINDGREN,† RICHARD MARRUS, AND M. RUBINSTEIN, *Lawrence Radiation Laboratory and University of California, Berkeley.*—The atomic-beam magnetic-resonance method has yielded the ground-state nuclear spins of three radioactive rare earths. The results are $I=7/2$ for 50-hr Pm^{149}, $I=5/2$ for 27-hr Pm^{151}, and $I=3$ for 72 d Tb^{160}. Zeeman transitions in the $J=7/2$ level of promethium were observed with a previously measured electronic g value.[1] The g values used for terbium were obtained from an atomic-beam experiment on stable Tb^{159}.[2] Interpretations of the nuclear spins are made on the basis of existing nuclear models.

* This research was sponsored by the U. S. Atomic Energy Commission and the Office of Naval Research.
† Now at the Institute of Physics, University of Uppsala.
[1] A. Cabezas, I. Lindgren, E. Lipworth, R. Marrus, and M. Rubinstein, "Nuclear spins of neodymium-147 and promethium-147," UCRL-9122 (to be published).
[2] S. Penselin and K. Schlüpmann, University of Heidelberg (private communication).

L11. Hyperfine Structure and Moments of Yttrium-90.* F. R. PETERSEN AND H. A. SHUGART, *University of California, Berkeley.*—The hyperfine structure separations for radioactive yttrium-90 ($T_{\frac{1}{2}}=64$ hr) have been measured in both the $^2D_{\frac{3}{2}}$ and $^2D_{\frac{5}{2}}$ electronic states by the atomic beam magnetic resonance method. The spin $I=2$ has been reported previously.[1] Eleven "flop-in" transitions in the $^2D_{\frac{5}{2}}$ state and ten "flop-in" transitions in the $^2D_{\frac{3}{2}}$ state corresponding to the high field transition $M_J=\pm1/2 \leftrightarrow \mp1/2$ have been observed. The interaction constants a and b fitted to these observations are $a\ (^2D_{\frac{5}{2}})=-169.749(15)$ Mc/sec, $b\ (^2D_{\frac{5}{2}})=-21.602(60)$ Mc/sec, $a\ (^2D_{\frac{3}{2}})=-85.258(15)$ Mc/sec, $b\ (^2D_{\frac{3}{2}})=-29.716(80)$ Mc/sec. The uncorrected nuclear magnetic moment calculated from the hyperfine structure using the magnetic moment[2] and interaction constants[3] of Y^{89} is $\mu_I=-1.623(8)$ nm. The sign of the moment was determined from the g_I-dependent $\Delta F=\pm1$ transitions for which the magnetic field dependence was zero at high fields. The uncorrected nuclear electric quadrupole moment calculated from the interaction constant b for both electronic states is $Q=-0.15(2)$ barn.

* Supported in part by the U. S. Air Force Office of Scientific Research and the U. S. Atomic Energy Commission.
[1] F. R. Petersen and H. A. Shugart, Bull. Am. Phys. Soc. Ser. II, 4, 452 (1959).
[2] E. Brun, J. Oeser, H. H. Staub, and C. G. Telschow, Phys. Rev. 93, 172 (1954).
[3] Fricke, Kopfermann, and Penselin, Z. Physik 154, 229 (1959).

FRIDAY AFTERNOON AT 1:30

310 Le Conte Hall

(S. D. DRELL presiding)

Theoretical Physics

M1. Coherent π^0 Photoproduction from Deuterium. FOKION T. HADJIOANNOU, *Stanford University.*—The calculation of elastic photoproduction of π^0 mesons from deuterium, $\gamma+D \rightarrow \pi^0+D$, is carried out in the impulse approximation at photon energies around 500 Mev.[1] The single nucleon photoproduction amplitudes are taken from dispersion formulas[2] and are corrected for kinematic effects due to internal momenta of the nucleons in the deuteron. We include the D-state part of the deuteron wave function, and we use different models with Yukawa type or repulsive core wave functions. We give formulas connecting the cross section with the deuteron form factors. For small momentum transfers the formulas are of course model independent and reduce to the usual ones. The presence of a 7% D state in a repulsive core model leads to a cross section which falls typically more slowly at high momentum transfers; e.g., at a momentum transfer 2.74 f^{-1}, the cross section is larger by about 40% than the cross section calculated in the absence of the D state. The experimental points favor this model.

[1] This calculation is done in connection with an experiment by J. Friedman and H. Kendall.
[2] G. F. Chew, M. L. Goldberger, F. E. Low, and Y. Nambu, Phys. Rev. 106, 1337 (1957).

M2. Global Symmetry and $K^- - p$ Reactions at Low Energy. MARC H. ROSS, *Indiana University,* AND GORDON L. SHAW, *University of California, La Jolla.*—Several attempts have been made to interpret low-energy K^--p reactions in terms of the πYN interaction. The weak coupling approach assumes that the amplitudes for π-Y elastic scattering in, e.g., the K matrix or, as recently suggested by Matthews and Salam, T^{-1} are not influenced by the $\bar{K}$-N channel. Thus they assume that the actual π-Y amplitudes of T^{-1} should be directly compared with global symmetry amplitudes to test global symmetry. By using our *nonperturbative* theory which employs methods similar to effective range techniques, we find that the phase ϕ of T matrix elements for $K^-+p \rightarrow \Sigma+\pi$ is essentially given by the phase of $(a^{-1}-R^{-1})$ plus phases calculated using uncoupled π-Y amplitudes in T^{-1}. Here R is the $\bar{K}$-N effective range and a the $\bar{K}$-N scattering length. We calculated $\phi_{I=0}-\phi_{I=1}$ at zero energy including effects of Λ production and the K^--$\bar{K}^0$ mass difference (neglected in a previous calculation) using the a's of Dalitz and Tuan and varying R from 0.3 to 0.6×10^{-13} cm. The results (contrary to those of the Matthews-Salam procedure) indicate that the b^- solution

(and possibly a^-) can be consistent with global symmetry for either $K\Sigma N$ parity.

M3. Two-Pion Exchange and Born Terms in K^+-p Scattering. GRAHAM FRYE AND ROBERT LEE WARNOCK, *University of Washington*, AND MODESTO PUSTERLA AND FABIO FERRARI, *Lawrence Radiation Laboratory, Berkeley.*—It has been suggested that the long-range force due to exchange of two pions can account for the supposed decrease in K^--p elastic scattering near threshold.[1] The same force must also have an effect on K^+-p scattering. The experimental cross section for the latter is rather flat as a function of energy and shows no indication of any low-energy P-wave scattering. We have attempted to understand this situation by constructing for the S and P scattering amplitudes an analytic function of total energy W which satisfies the unitarity condition in the physical region and which has a few dynamical singularities (i.e., poles in the unphysical region) representing the two-pion exchange and Born terms. Interference effects between the several terms are discussed as well as the influence of different parity assignments. S wave data are used to determine the strengths of the dynamical singularities. A comparison of these is made with the parameters obtained from the K^--p data. Finally, the predictions of the model for P waves are noted.

[1] F. Ferrari, G. Frye, and M. Pusterla, Phys. Rev. Letters 4, 615 (1960).

M4. Partially Conserved Currents and the K'-Meson. JEREMY BERNSTEIN, *Brookhaven National Laboratory*, AND STEVEN WEINBERG, *University of California.*—It recently has been suggested by Gell-Mann, Tiomno, and others that there may exist an unstable K' meson, similar but of opposite parity to the K meson, which can show up as a distinct resonance in strange-particle reactions. If it is assumed that such a resonance dominates (wherever selection rules allow) in $K_{\mu 3}$ and K_{e3} decay, and that the $K \to \pi$ matrix element of the divergence of the weak interaction current (presumed a "gentle" operator) satisfies an *unsubtracted* dispersion relation, then it is possible to make a unique prediction of all features of $K_{\mu 3}$ and K_{e3} decay (spectrum, angular correlation, etc.) with the exception of the integrated decay rate. Partial information also can be gained in a similar way about hyperon beta decay.

M5. Trident Production and Quantum Electrodynamics at Small Distances. MAO-CHAO CHEN, *Stanford University.*—The cross section for production of an electron-positron pair by an electron incident on a proton (tridents) has been proposed and studied approximately[1] as a probe of quantum electrodynamics at small distances. In this work the trident cross section is calculated accurately including all terms of order e^4 in the matrix element. Electrons and positrons are treated in the extreme relativistic limit, and the proton is treated as a point source of Coulomb potential. This approximation is shown to be justified for the planned experimental conditions. One electron and positron of the emerging beam are to be detected by a coincidence experiment so that the angle and energy parameters of the undetected electron are integrated over. A complicated analytical expression has been derived and is being numerically evaluated for various energies and angles.

[1] J. D. Bjorken and S. D. Drell, Phys. Rev. 114, 1368 (1959).

M6. Theory Concerning the Unification of Electromagnetism and the Weak Interactions. R. E. NORTON, *University of California at Los Angeles*, AND P. E. KAUS AND W. K. R. WATSON, *University of Southern California.*—Earlier suggestions[1] have been modified by the introduction of four vector bosons coupled to leptons through a term of the form $g\bar{\Psi}\Gamma_\mu\tau_i\Psi X_\mu^i$, where τ_i are the usual Pauli spin matrices, τ_4 is the unit matrix, and Ψ is a doublet in "isotopic spin" space representing an (e^-,ν) or (μ^-,ν') pair. By insisting that the Lagrangian is invariant under rotations about the z axis in this space and under the transformation $\Psi_\nu \to \gamma_5\Psi_\nu$ (to insure that the neutrino acquires no mass as a result of this interaction), one obtains the usual electromagnetic and $(V\text{-}A)$ weak couplings to the leptons together with a neutrino-neutrino pseudovector interaction to a neutral vector boson of the form $g\bar{\Psi}\gamma_\mu[(a+\vec{a}\tau_e),\tau_i]\Psi X_\mu^{(i)}$. This scheme can be extended in a natural way to include the strangeness conserving part of the weak decay current, together with the usual baryon electric current coupled to the electromagnetic field. The extension of this theory to the nonstrangeness conserving processes is presently being considered.

[1] J. Ward and A. Salam, Nuovo cimento (1958).

M7. Quantum Electrodynamics: I. A Generalized Maxwell-Lorentz Theory of Electrodynamics. SOLOMON L. SCHWEBEL AND MENDEL SACHS, *Lockheed MSD.*—The classical Maxwell equations of electrodynamics are written in two uncoupled covariant spinor equations, $\sigma_\mu\partial_\mu\phi_\alpha = \mathrm{T}_\alpha (\mu = 1, 2, 3, 4)(\alpha = 1, 2)$. If $G_i = H_i - iE_i$, then ϕ_1 is a two-component spinor such that $\phi_{11} = G_3$; $\phi_{12} = G_1 + iG_2$ and ϕ_2 is $\phi_{21} = -G_1 + iG_2$ and $\phi_{22} = G_3$. Similarly $\mathrm{T}_{11} = 4\pi i(-\rho + J_3)\mathrm{T}_{12} = 4\pi i(J_1 + iJ_2)$ and $\mathrm{T}_{21} = 4\pi i \times (-J_1 + iJ_2)$; $\mathrm{T}_{22} = 4\pi i(\rho + J_3)$. Among other forms left invariant by proper Lorentz transformations are $\phi_\alpha{}^+ \mathrm{T}_\beta \times (\alpha, \beta = 1, 2)$. Linear combinations of these give a generalized Lorentz force which has been discussed elsewhere.[1,2] Maxwell's equations are interpreted as a tautology, which covariantly determine the field variables ϕ_α associated with the source T_α. If there are no source terms, there are no field variables and vice versa. Consequently solutions to the homogeneous equations have no physical meaning. Moreover, a source cannot act on its field or be acted upon by it. The problems of self-force, self-energy, etc., are circumvented. Classical quantities are not significantly changed by this interpretation. For example, $E^2 + H^2$ is replaced by $E^{(p)} \cdot E^{(q)} + H^{(p)} \cdot H^{(q)}$—the superscripts take into account the different sources of the field quantities. The implication for quantum electrodynamics is, however, all important.

[1] M. Sachs, Ann. Phys. 6, 244 (1959).
[2] M. Sachs and S. L. Schwebel, Lockheed Missiles and Space Division, LMSD 288254 (1960).

M8. Quantum Electrodynamics: II. A Self-Consistent Field Theory. MENDEL SACHS AND SOLOMON L. SCHWEBEL, *Lockheed MSD.*—A self-consistent field theory of quantum electrodynamics has been developed which is based on the postulate that the laws of nature must be described in terms of field variables which may be interpreted only in terms of elementary interactions between particles. Free fields and self-energy play no role in the theory. The derived field equations are a set of coupled nonlinear differential equations equal in number to the number of constituent particles. Their solutions are functions only of the space-time coordinates x, defining a point of interaction of all particles. The theory is a nonsingular, deterministic, and completely covariant field theory. Quantum mechanics is interpreted as a statistical theory of elementary interactions. The Lagrangian formalism is used to derive the field equations and conserved properties of the system. The Lagrangian depends on the Dirac field variables ψ, $\bar{\psi}$ and the Maxwell spinor variables ϕ_α, $\phi_\alpha{}^+$ (see preceding abstract) for each of the particles. Application to a system of identical particles gives the Pauli principle. An exact solution, obtained for the electron-positron system, exhibits all physical properties associated with pair annihilation. Electromagnetic coupling to a third particle causes pair creation. The linearization of the field equations for the electron-proton system is carried out by allowing $m_p \to \infty$. The resulting equation contains an extra term, giving rise to a Lamb shift.

M9. Electron-Proton Bremsstrahlung. R. A. BERG AND C. N. LINDNER, *Stanford University.*—The electron-proton bremsstrahlung cross section is calculated in first Born approximation, neglecting radiative corrections to the electron. As an extension of an earlier calculation, we here analyze the proton Compton effect contribution in its most general form. It will involve twelve form factors of three invariants: $f_j(\nu_1,\nu_2,\nu_3)$, $(j=1,\cdots,12)$. The cross section is stated explicitly in terms of these twelve functions and the two form factors of one invariant describing the proton vertex. The contributions to the f_j from (a) the single nucleon intermediate state, (b) the one meson plus one nucleon intermediate state, and (c) the neutral pion exchange are calculated. These three contributions are expected to be the major effects when the energies involved are in the range of present experimental interest. To order $(1/M)^2$, when only (a) and (b) are considered, only two combinations of these twelve f_j will contribute to the cross section.

M10. Radiative Corrections to the *e-p* Scattering. YUNG SU TSAI, *Stanford University.*—The radiative corrections to the *e-p* scattering are calculated including the effects of the proton recoil. We assumed the experimental conditions of Hofstadter *et al.* of Stanford, namely, that only the final electrons are momentum analyzed. Let ΔE be the energy difference between the elastic peak and the threshold of the detector; then the maximum energy of photons which can be emitted is ΔE in the final electron direction but $\eta^3\Delta E$ in the incident electron direction, where η is the ratio of the energy of the initial electron to that of the final electron. This effect decreases the radiative corrections, say at 145°, by about 6.5% at incident energy of 900 Mev. The effect due to the radiations from the proton current also is calculated. It increases the radiative corrections by about 4% for e^--p scattering under the above conditions and $\Delta E/E_{\text{final}}=4\%$. (For e^+-p scattering this effect decreases the radiative correction by about 2.4%.) The aforementioned two effects will be more pronounced at higher energies and larger scattering angles. Our formula probably will be good up to about 5 Bev.

M11. Electromagnetic Interactions of Charged Spin One Mesons. J. A. YOUNG, *Lawrence Radiation Laboratory, Berkeley* (introduced by S. A. BLUDMAN).—Starting with the most general first-order Lagrangian for a charged spin one meson, the redundant components are eliminated, and a Hamiltonian of the Sakata-Taketani type is obtained. The terms corresponding to magnetic dipole and electric quadrupole moment are identified in the nonrelativistic limit. The equations obtained are compared with those obtained in other formalisms, and the resulting interaction is applied to the calculation of the rate of $\mu \to e+\gamma$ through a weakly coupled charged vector meson.

FRIDAY AFTERNOON AT 2:00

4 Le Conte Hall

(W. SHOCKLEY presiding)

Solid State, Semiconductors

N1. Ultimate Yield Strength of Copper.* R. G. MCQUEEN AND S. P. MARSH, *Los Alamos Scientific Laboratory* (introduced by W. E. Deal).—Copper specimens were subjected to large tensile stresses by colliding explosive-driven, thin copper plates with thick (2–5 cm) plates holding the samples. The collision first produces strong shock waves, up to 600 kb, that propagate in both directions from the impact interface. When these shock waves reach the opposite surfaces, the pressure is relieved by simple centered rarefaction waves which propagate back into the plates. The subsequent interaction of these rarefaction waves cause the tensions necessary to strain the metal to the yield point. Since there is momentum available in excess of that required to simply break or spall the material, spallation is accompanied by vaporization or ablation of material after the yield point is reached. The amount of material ablated as determined by measurements on the recovered pieces and the corresponding hydrodynamic calculation form the principal criteria for establishing the yield point. Present results indicate that the true yield point of copper under tension is in excess of 100 kb. The equation of state of copper used in the calculations is discussed.

* Work done under auspices of the U. S. Atomic Energy Commission.

N2. Investigation of the Hugoniot Elastic Limit in Armco Iron by Optical Reflection Measurements.* S. P. MARSH AND R. G. MCQUEEN, *Los Alamos Scientific Laboratory* (introduced by W. E. Deal).—An optical system similar to that described by Allen and McCrary[1] was used to measure the Hugoniot elastic limit in Armco iron. A sweeping image camera photographed a row of highly illuminated point sources in the polished surface of a 10° Armco iron wedge. This wedge was mounted on plane flat pieces of Armco iron of various thicknesses which were shock loaded by a plane-wave explosive system designed so that the longitudinal elastic wave runs ahead of the main compressive pulse. When the elastic wave reaches the front surface of the wedge, the point images in the film plane are displaced a distance that is directly proportional to the free-surface velocity of the iron. As the sample thickness is increased, it is found that the yield point decreases and that the elastic wave front becomes smeared out. The latter phenomenon can be explained with a simple equation of state model coupled with viscous effects; the former, however, cannot, which indicates that relaxation effects are probably acting.

* Work done under auspices of the U. S. Atomic Energy Commission.
[1] W. A. Allen and C. L. McCrary, Rev. Sci. Instr. 24, 165 (1952).

N3. Thermal and Electrical Behavior of Semiconducting Cerium Sulfide at High Temperatures.* S. W. KURNICK, M. CUTLER, AND R. L. FITZPATRICK, *General Atomic.*†—The thermoelectric and electrical properties of the compound $Ce_{2+x}S_{3+x}$, $0\leq x\leq 1$, at high temperatures show a marked dependence on the S/Ce ratio. Conductivity of the single phase compound varies from insulator 10^{-8} ohm cm to that of a semi-metal 10^{-3} ohm cm. Low mobilities of this material and the increase in Seebeck potential with temperature suggests a polaron model not unlike that of NiO and α-Fe_2O_3.[1,2] The behavior of other transport properties, such as Seebeck potential and thermal conductivity vs temperature, are discussed. Measurement of thermoelectric parameters, particularly the thermal conductivity, is difficult because of the tendency for samples to have cracks. Because of this, the small area contact method was used to measure the thermoelectric parameters ranging up to 1500°C.[3] The procedures

used for adapting this technique to measuring cerium sulfide and the experimental results will be described.

* The work described in this paper was done under a Bureau of Ships contract.
† John Jay Hopkins Laboratory for Pure and Applied Science, General Atomic Division of General Dynamics Corporation, San Diego, California.
[1] F. J. Morin, Phys. Rev. Letters 3, 34 (1959).
[2] J. Appel, Phil. Mag. (to be published); G. L. Sewell, Phil. Mag. 36, 1361 (1958).
[3] M. Cutler, Bull. Am. Phys. Soc. Ser. II, 5, 281 (1960); General Atomic Report, GA-1674, September 15, 1960.

N4. Low-Temperature Length Change Measurements on Electron Irradiated Silicon. FREDERICK L. VOOK, *Sandia Laboratory.*—Precision measurements of the change in length of high-purity, vacuum-floating-zone, single-crystal silicon were made upon irradiation and annealing. The specimen was initially irradiated at ~50°K with 2-Mev electrons to an integrated flux of 8.3×10^{18} electrons/cm² and further irradiated at ~115°K to a total integrated flux of 7.9×10^{19} electrons/cm² and then annealed to room temperature. The specific length expansion for both bombardments obtained by a least-squares fit of the bombardment curve was $\Delta L/L=3.8\pm19.4\times10^{-26}$ per 2 Mev electrons/cm². No significant change in length was observed upon annealing to room temperature. By using the Seitz-Koehler simple theory of displacement, assuming no annealing at the low temperatures, we calculate a concentration of displaced pairs equal to 3×10^{-3}. We find that the corresponding fractional atomic volume change of interstitial-vacancy type defects in silicon is such that $(f_i+f_v)=0.003\pm0.015$ or ≤0.018 which is an order of magnitude smaller than that found in deuteron irradiated germanium.

N5. An Effect of Thermal History on the Residual Resistivity of Sodium.* R. F. POST AND C. E. TAYLOR, *Lawrence Radiation Laboratory, Livermore.*—The residual electrical resistivity of sodium at temperatures of a few degrees Kelvin is independent of temperature and seems to depend primarily on the atom percent of impurities in solid solution. We have found a strong effect, tending to reduce the residual resistivity, associated with the thermal history of encapsulated high-purity sodium conductors. If such a conductor is heated and held at a temperature a few degrees below the melting point of sodium, its residual resistance decreases with time. After being held at this temperature for several days, the sample resistance, measured at liquid helium temperature, asymptotically approaches a value which may be as much as a factor 3 lower than that before heating. The decrease is most pronounced for the most impure samples and for those of largest cross section, suggesting that size or other effects also may be present. Since sodium already becomes fully annealed at temperatures below room temperature, and since the mean impurity content of encapsulated samples is clearly constant, we conjecture that the effects observed may arise from impurity atom migration and clustering, possibly associated with crystal growth in the sample.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

N6. Transverse Magneto-Resistance Measurements on Large Sodium Conductors.* C. E. TAYLOR AND R. F. POST, *Lawrence Radiation Laboratory, Livermore.*—Transverse magneto-resistance measurements were made on sodium samples of much larger cross section and length than those previously used. Distilled sodium was encapsulated in 530-cm-long by 12-mm-diam coiled stainless steel tubes. Two current supply wires and 5 potential pickup wire pairs were attached to the tube wall. Fields up to 18 000 gauss and samples with zero field residual resistivity ratios ($R_{0°C}/R_{4.2°K}$) of up to 7000 were used. Approximate quantitative agreement with previous measurements[1] was obtained. However, some anomalously low values were obtained for intermediate portions of the same coil; furthermore, the magneto-resistance is linear with field below about 1500 gauss, and above about 3000 gauss it is proportional approximately to the 0.6 power of the field.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] G. K. White, and S. B. Woods, Phil. Mag. 1, 846 (1956).

N7. Observation of Indirect Tunneling via Impurity States in Narrow Silicon Junctions. C. T. SAH, *Fairchild Semiconductor Corporation.*—Impurity induced excess currents have been observed in silicon doped with metal which has one or several energy levels in the energy gap. Of the several impurities investigated (Zn, In, Tl, Ni, Mn, and Au), gold gives the greatest excess current which is experimentally observed to be proportional to the gold concentration. Excess currents of all the other impurities stated are about one to two orders of magnitudes smaller than the phonon-assisted peak current; however, their presence is readily observed (except Mn) in the current-voltage or the conductance-voltage characteristics at 4.2°K. The structures corresponding to the on-set and off-set of the impurity induced currents are observed at the following voltages at 4.2°K: Au(400,720, 930 mv); Zn(350,500 mv); In(220,400 mv); Tl(380,550 mv); Ni(550,865 mv); and Mn (no structure probably because of too low concentration). These experimental results may be interpreted as due to electron tunneling transition across the junction barrier via the impurity levels as intermediate states. However, the shape of the excess current-voltage characteristics observed at 4°K cannot be explained in terms of a sharp impurity ground state.

N8. Photogalvanic Effect of Copper Single Crystals. DUDLEY A. CHANCE AND KEN NOBE, *University of California, Los Angeles.*—Photovoltages of copper single crystals in air-saturated, double-distilled water at room temperature have been measured. A slide projector with a tungsten lamp served as the light source. The electrodes of the galvanic cell were identical pieces of the same crystal. The illuminated electrode assumed an almost instantaneous negative potential with a rapid decay to a positive potential. This steady-state positive potential varied linearly with light intensity. The maximum potential observed was 2.7 mv for an intensity of 1.9 w/cm² when the single crystal was immersed in water for 3 days. The results indicate that the photovoltage increases with thickness of the Cu_2O film in accord with Kruger's[1] observation that illumination inhibits oxide growth of copper single crystals. The sign of the electrode potential of the illuminated crystal is predicted by Williams'[2] model for *p*-type semiconductors. Results of photopotentials and transient responses of a second copper single crystal with a different crystallographic orientation will be discussed. Transient and steady-state photopotentials of these two single crystals in sodium chloride solutions will be reported.

[1] J. Kruger, J. Appl. Phys. 28, 1212 (1957).
[2] R. Williams, J. Chem. Phys. 32, 1505 (1960).

N9. Effect of Magnetic Directional Ordering on Damping in Fe-Al Alloys. D. B. FISCHBACH, *Jet Propulsion Laboratory,** *C.I.T.*—According to Néel and Taniguchi, solute atoms in magnetic alloys may order with respect to the local direction of magnetization, thus affecting the magnetic properties. Effects of domain wall anchoring by such directional ordering have been observed in the low-frequency damping of Fe-Al alloys containing 8–21 atomic percent Al. The magnetoelastic damping, resulting from stress-induced motion of domain walls, is normally amplitude-dependent and varies only slowly with temperature. Directional ordering produces three modifications of this behavior: (1) The amplitude-dependent component disappears below a critical breakaway stress which increases with solute concentration and inverse temperature. (2) The amplitude-dependent component is enhanced by

demagnetization or high-amplitude oscillation but decays to the original value at a rate which increases with temperature. (3) An amplitude-independent magnetic component appears and produces a damping peak at high temperatures. (1) is attributed to breakaway of domain walls initially anchored by directional order. This order can be destroyed by demagnetization but reforms with time, producing (2). The magnetic damping peak (3) is attributed to the diffusion-limited stress-induced motion of anchored domain walls.

* A contract facility of the National Aeronautics and Space Administration.

N10. Paramagnetic Resonance Detection of Charge Association in Zinc Sulfide. R. S. TITLE, *IBM Research Center, Yorktown Heights.*—Unactivated zinc sulfide fired at 1100°C in a hydrogen sulfide atmosphere shows no EPR absorption in the dark. Illumination with radiation peaked at 360 mμ results in an EPR absorption. This consists of a peak at $g=2.00$ with smaller hfs peaks centered about $g=2$. The spectrum is isotropic. The illumination is considered to effect a charge transfer from an activator to a trap, in this case from a cation vacancy to an aluminum ion with which it is associated. Intentional addition of aluminum to the zinc sulfide results in a continuous shift to lower energies of the radiation required to excite the resonance, thus indicating a charge association between the added aluminum and the zinc vacancies. Similar shifts in energy have been observed in zinc sulfide samples to which gallium or indium have been added.

FRIDAY EVENING AT 7:00

(Cocktails from 6:00)

Claremont Hotel

(V. F. WEISSKOPF presiding)

Banquet of the American Physical Society

After-dinner speech: **Teaching of Physics.** EMILIO SEGRÈ, *University of California and Lawrence Radiation Laboratory, Berkeley.*

SATURDAY MORNING AT 9:30

310 Le Conte Hall

(R. HOFSTADTER presiding)

High-Energy Nuclear Physics

O1. Nucleon-Nucleon Elastic Interactions at 1 Bev. G. MARTELLI, H. B. VAN DER RAAY, R. RUBINSTEIN, K. R. CHAPMAN, J. D. DOWELL, W. R. FRISKIN, AND B. MUSGRAVE, *University of Birmingham* (introduced by W. E. Burcham).—Proton-proton and proton-neutron elastic interactions have been studied with the Birmingham proton synchrotron, using fast counter techniques in conjunction with magnetic momentum analysis. From the measured cross sections, information about the $T=0$ and $T=1$ scattering amplitudes has been deduced. Details of the experimental arrangement and an interpretation of the results will be given.

O2. Multiple Pion Production by 2.85-Bev Protons.* E. L. HART, R. I. LOUTTIT, D. LUERS,† T. W. MORRIS, W. J. WILLIS, AND S. S. YAMAMOTO, *Brookhaven National Laboratory.*—The reactions: (1) $p+p \rightarrow p+p+\pi^+ +\pi^-$, (2) $p+p \rightarrow p+p+\pi^+ +\pi^- +\pi^0$, (3) $p+p \rightarrow n+p+\pi^+ +\pi^+ +\pi^-$, have been studied in the BNL 20-in. hydrogen bubble chamber exposed to a 2.85-Bev proton beam. In a group of 490 events, 270 were identified as reaction (1), 78 as reaction (2), and 142 as reaction (3). Since the data may be affected by as yet unevaluated biases, errors should be considered to be larger than those due to statistics. The center-of-mass momentum spectra of all the pions, except the negative pions in reactions (1) and (2), are peaked in the region 200–300 Mev/c. Presumably this effect is due to the $T=3/2$ resonance. The protons in reaction (1) are peaked at forward and backward angles, and at high momenta, in the center of mass. Further results, including total cross sections for the above reactions and Q-value distributions, will be presented.

* Work performed under auspices of U. S. Atomic Energy Commission.
† On leave from Max Planck Institute, Munich, West Germany.

O3. An Indirect Measurement of the Neutral Pion Lifetime.* H. RUDERMAN, S. BERMAN, R. GOMEZ, A. V. TOLLESTRUP, AND R. TALMAN, *California Institute of Technology.*—The lifetime of the neutral pion has been determined by measuring the cross section for the inverse process, i.e., π^0 photoproduction from a Coulomb field.[1] The differential cross section is given by $d\sigma/d\Omega_\pi = 8Z^2 \propto (\hbar c/\mu)^2(\hbar/\mu\tau)\beta^2 F^2(q^2) \sin^2\theta_\pi/q^4$, where μ is the pion mass, τ is the pion lifetime, q is the momentum transfer to the nucleus, and $F(q^2)$ is the nuclear form factor. Both decay gamma rays from the pions produced by a 1.2-Bev bremsstrahlung beam from the Cal Tech synchrotron in lead or copper targets are detected by a pair of total absorption Čerenkov counters which are placed in fast coincidence. The pion energy, angular distribution, and the correlation of the two gamma-ray energies are used to separate the Coulomb process from coherent and incoherent nuclear production. The incoherent nuclear production appears to be suppressed below A times the small angle hydrogen cross section, and in lead is less than 14 μb/sr. A preliminary fitting of the data to the Coulomb and coherent nuclear processes and their interference gives the π^0 lifetime as $(1.7\pm1.4)\times10^{-16}$ sec. It is hoped that data at higher synchrotron energies will result in a more accurate value of the lifetime.

* This work is supported in part by the U. S. Atomic Energy Commission.
[1] H. Primakoff, Phys. Rev. 81, 866 (1951).

O4. Low-Energy Photon Scattering by Pions. BIPIN R. DESAI, *Lawrence Radiation Laboratory, Berkeley.*—We have studied Compton scattering by pions[1] to see if a low-energy resonance in the $\pi\pi$ system, such as conjectured by Frazer and Fulco, will produce a strong deviation from the equivalent of the Klein-Nishina formula. Calculations were based on dispersion relations at fixed momentum transfer for the two independent gauge invariant amplitudes. No subtraction constants are required when these amplitudes are properly chosen, and the Thomson limit is automatically maintained. The contribution of the 2π intermediate state is determined by the amplitude for the process $\gamma+\pi\to 2\pi$ which has been analyzed by How-sen Wong and shown to be proportional to a pseudo-elementary constant A. Even with a sharp $\pi\pi$ resonance in the $I=1$, $J=1$ state, it turns out that the 2π contribution to photon scattering is very small ($\lesssim 1\%$), if we use the estimate of A made by Wong on the basis of π^0 decay and confirmed by Ball in connection with photopion production from nucleons. Because of the smallness of A, therefore, Compton scattering by pions, even if experimentally feasible, would not be a promising method for studying the $\pi\pi$ interaction.

[1] It has been brought to our notice that another independent investigation is being carried out by M. Gourdin and A. Martin, CERN preprint 8142/Th. 8.

O5. Production of Pion Pairs by a Photon in the Coulomb Field of a Nucleus. YONGDUK KIM, *Lawrence Radiation Laboratory.*—A theoretical study, based on the Mandelstam representation, has been made of the production by multi-Bev photons of pion pairs in the nuclear Coulomb field. Three independent invariant amplitudes must be considered because a virtual photon of nonzero mass participates, as well as the real incident photon. In principle, the pair production amplitude depends on the constant A introduced by How-Sen Wong in connection with the process $\gamma+\pi\to\pi+\pi$.[1] However A is so small that in practice the only strong interaction complication enters through the final state $\pi\pi$ S-wave phase shifts. Calculations are being performed for a variety of assumptions about these S-phase shifts.

[1] How-Sen Wong, "Low-energy photopion production from pions and neutral-pion decay" (thesis), University of California, Berkeley, UCRL-9251, and Phys. Rev. Letters 5, 70 (1960).

O6. K^- Interactions in Hydrogen at 760, 640, and 520 Mev/c.* P. BASTIEN, O. DAHL, D. MILLER, J. J. MURRAY, F. SOLMITZ, AND R. TRIPP, *Lawrence Radiation Laboratory, Berkeley.*—A 15-in. hydrogen bubble chamber has been exposed to the separated beam of K^- mesons at Berkeley.[1] The following preliminary values have been obtained for the total cross sections: 40 ± 2 mb at 760 Mev/c, 38 ± 3 mb at 640, 48 ± 4 mb at 520. The quoted errors account for statistics and uncertainty in pion contamination; however, uncertainties in scanning efficiency have not yet been determined.

* This work was supported in part by the U. S. Atomic Energy Commission.
[1] P. Schlein, P. Bastien, O. Dahl, J. J. Murray, M. Watson, and R. G. Ammar, paper presented at the International Conference on Instrumentation for High-Energy Physics, Berkeley, 1960.

O7. Evidence for the Production of an Excited $\Delta\pi$ State in the Reaction $K^-+p\to\Lambda+\pi^++\pi^-$ by 760-Mev/c K Mesons.* M. FERRO-LUZZI,† J. P. BERGE, J. KIRZ, J. J. MURRAY, A. H. ROSENFELD, AND M. WATSON, *Lawrence Radiation Laboratory, Berkeley.*—A 15-in. hydrogen bubble chamber exposed to a separated K^- beam at 760 Mev/c[1] gives a cross section of 2.7 ± 0.1 mb for events with two charged prongs and a V. Kinematic analysis of 245 such events apportions them into $\pi^++\pi^-$ plus: Λ(176 events), Σ^0(28), ambiguous between these two (<24), and $\Lambda+\pi^0$ or $\Sigma^0+\pi^0$(13); also $\bar{K}^0+p+\pi^-$(4). Alston *et al.*[2] have reported evidence for the reaction $K+p\to Y^{*\pm}+\pi^{\mp}$, where $Y^{*\pm}$ represents an excited state of Λ at $\sim$1380 Mev, decaying into $\Lambda+\pi^{\pm}$. We find that 70% of the 200 events classified above as $\Lambda+\pi^++\pi^-$ (including all 24 ambiguous ones) are consistent with Y^* production, if Y^* has a mass of 1380 ± 15 Mev. These 70% of the events fall in 25% of the phase space available for the direct production of $\Lambda+\pi^++\pi^-$.

* This work was supported in part by the U. S. Atomic Energy Commission.
† National Academy of Sciences Fellow.
[1] P. Schlein, P. Bastien, O. Dahl, J. J. Murray, M. Watson, and R. G. Ammar, paper presented at the International Conference on Instrumentation for High-Energy Physics, Berkeley, 1960.
[2] M. Alston, L. W. Alvarez, P. Eberhart, M. L. Good, W. Graziano, H. K. Ticho, and S. Wojcicki, paper presented at the Tenth International Conference on High-Energy Physics, Rochester, 1960.

O8. Electron Triplet Production by High-Energy Photons in Hydrogen.* DUANE C. GATES, ROBERT W. KENNEY, AND WILLIAM P. SWANSON, *Lawrence Radiation Laboratory, Berkeley.*—5417 triplets and 4019 pairs, produced by a 323-Mev hardened bremsstrahlung beam in a 4-in.-diam hydrogen bubble chamber, were analyzed with the following results: (a) The ratio of apparent triplets to apparent pairs was 0.291 ± 0.0097. (b) The experimental triplet cross sections for detectable recoils (momentum greater than 0.27 Mev/c), and for recoils with momentum greater than mc, rise logarithmically with photon energy to 100 Mev, then level off at approximately 2.8 mb and 1.5 mb, respectively. (c) The total triplet cross section agrees with that of Borsellino above 20-Mev photon energy. If the contribution to the Borsellino cross section of the exchange terms is taken to be of the form $-B(\alpha r_0^2)(mc^2/k)\ln(2k/mc^2)$, then B is 2.4 ± 7.4. (d) The positron energy distribution agrees with that of Wheeler and Lamb. (e) The recoil-momentum distribution agrees substantially with that of Suh and Bethe; however, their result is slightly too large in the region of large recoil momenta. (f) Recoils with momenta greater than 1 Mev/c predominate on the small-angle side of a peak at 50 deg. (g) No events caused by multiple pair production were found.

* Supported by the U. S. Atomic Energy Commission.

O9. π^-–p Elastic Scattering at 550, 600, 720, 900, and 1020 Mev.* CALVIN D. WOOD, THOMAS J. DEVLIN, JR., JEROME A. HELLAND, MICHAEL J. LONGO, BURTON J. MOYER, AND VICTOR PEREZ-MENDEZ, *Lawrence Radiation Laboratory, Berkeley.*—The differential elastic scattering cross sections for negative pions on hydrogen were measured at the above energies using a pion beam from the Berkeley Bevatron. These energies were chosen to cover the region of the second and third resonances in the total cross section.[1] By using scintillation counters, measurements were made at sixteen laboratory angles ranging from 7° to 165°. Elastic collisions were identified in two ways: for angles less than 30° in the laboratory, recoil proton counters were used in coincidence with the pion counters; for the forward angles, magnetic bending was used to separate elastic from inelastic events. A gas Čerenkov counter[2] was used to analyze the incident pion beam for contamination due to electrons and negative muons. The statistical accuracy of these data is considerably better (2–3%) than previous measurements in this region. The differential cross sections will be presented with emphasis on experimental problems.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] Devlin, et al., Phys. Rev. Letters 4, 242 (1960).
[2] J. H. Atkinson and V. Perez-Mendez, Rev. Sci. Instr. 30, 864 (1959).

SATURDAY MORNING AT 9:30

1 Le Conte Hall

(I. PERLMAN presiding)

Invited Papers on Low-Energy Nuclear Physics

P1. Single-Particle States in Deformed Nuclei. F. S. STEPHENS, JR., *Lawrence Radiation Laboratory, Berkeley.* (30 min.)

P2. Pairing Correlation Effects in Deformed Nuclei. S. G. NILSSON, *Lawrence Radiation Laboratory, Berkeley.* (30 min.)

P3. Evaporation of Particles from Rapidly Rotating Nuclei. I. HALPERN, *University of Washington.* (30 min.)

P4. Two-Nucleon Stripping Reactions. N. K. GLENDENNING, *Lawrence Radiation Laboratory, Berkeley.* (30 min.)

SATURDAY MORNING AT 9:30

4 Le Conte Hall

(ROLAND E. MEYEROFF presiding)

Solid State, Shock Waves

Q1. On the Possibility of Detecting Shock Induced Second-Order Phase Transitions in Solids. DONALD R. CURRAN, *Stanford Research Institute* (introduced by G. E. Duvall).—First-order phase changes in shock loaded solids have been previously detected from the formation of multiple wave structures in the solids.[1] It is shown theoretically that a multiple shock structure under shock loading also may be produced by a second-order phase transition. Therefore, the possibility of detecting shock-induced demagnetization of ferromagnetic metals and alloys is discussed, and an experimental attempt to detect such a demagnetization in shock-loaded Invar (64 Fe 36 Ni) is reported. Extrapolation of data by Patrick[2] suggests a Curie point transition in Invar in the neighborhood of 50 kilobars. The Hugoniot equation of state of Invar has been obtained over a pressure range of 40 to 60 kilobars. Although there is evidence of a large compression below 40 kilobars, there is no evidence of a multiple shock structure in the observed pressure range. The possibility that the Curie point transition is a factor in the multiple shock formation in iron also is discussed.

[1] R. E. Duff, and S. Minshall, Phys. Rev. **108**, 5, 1207 (1957).
[2] L. Patrick, Phys. Rev. **93**, 3, 384 (1954).

Q2. Equation of State of Metals from Shock Data to 4 mb.* DONALD G. DORAN,† *Washington State University* (introduced by G. E. Duvall).—The thermodynamic technique developed by Walsh *et al.*[1,2] for deducing isentropes from shock Hugoniots has been applied to the strong shock data of Al'tshuler, Krupnikov, and Brazhnik[3] which extends to 4 mb. Below 0.5 mb the data of Walsh *et al.* was used. The Slater expression was employed for the volume dependence of the Gruneisen ratio γ. The resulting $\gamma(V)$ curves will be compared with those of Walsh *et al.* and the more recent results of McQueen and Marsh[4] based on the Dugdale-MacDonald expression for γ. Zero degree isotherms and shock temperature estimates will be presented, the latter ranging from 15 000°K for copper to 58 000°K for lead at 4 mb.

* Supported in part by the National Science Foundation.
† Now at Poulter Laboratories, Stanford Research Institute.
[1] J. M. Walsh, M. H. Rice, R. G. McQueen, and F. L. Yarger, Phys. Rev. **108**, 196 (1957).
[2] M. H. Rice, R. G. McQueen, and J. M. Walsh, *Solid State Physics* (Academic Press, Inc., New York, 1958), Vol. 6, p. 1.
[3] L. V. Al'tshuler, K. K. Krupnikov, and M. I. Brazhnik, Soviet Phys.–JETP **34**, 614 (1958).
[4] R. G. McQueen and S. P. Marsh, J. Appl. Phys. **31**, 1253 (1960).

Q3. Shock Wave Compression of Hardened and Annealed 2024 Aluminum.* G. RICHARD FOWLES, *Stanford Research Institute* (introduced by G. E. Duvall).—Application of elastic-plastic theory to plane shock waves in metals predicts that the stress normal to the front is larger than the hydrostatic pressure necessary to produce the same compression by an amount equal to two-thirds the yield strength in simple tension. Experiments designed to observe such differences (~1.2 kb) in the Hugoniot equation of state for hardened and annealed 2024 aluminum are described. Oblique shock geometry was employed.[1] Shock and free-surface velocities were recorded with a smear camera by an optical lever technique.[2] This technique provides continuous recording of free surface velocities with time, an essential requirement because of the existence of a double wave system. Observed elastic wave amplitudes (5.4 and ~1.0 kb) agree within experimental precision with predicted values. The shock wave data (20 to 50 kb) yields one-dimensional strain isotherms which agree within experimental precision with semitheoretical curves based on Bridgman's hydrostatic data to 30 kb and simple tension stress-strain data. (No significant strain rate effects are observed.) It is concluded that elastic-plastic theory is valid for the description of plane shock waves in this material.

* Supported by the U. S. Air Force Office of Scientific Research.
[1] S. Katz, D. G. Gordan, and D. R. Curran, J. Appl. Phys. **30**, 568 (1959).
[2] W. Allen, and C. L. McCrary, Rev. Sci. Instr. **24**, 165 (1952).

Q4. Shock-Wave Compression of Quartz.* JERRY WACKERLE, *Los Alamos Scientific Laboratory.*—By means of explosive plane-wave systems shock waves of pressures ranging from 80 to 800 kilobars have been induced into x-cut, y-cut, and z-cut crystalline quartz and in fused quartz. High-speed streak camera observations of shock and free-surface velocities have demonstrated that a two-wave structure is developed in the crystalline samples below 500 kilobars. The first of these waves is associated with the Hugoniot elastic limit in the quartz and the second with the usual plastic flow. Elastic limit pressures and compressions are observed to vary with the axis of wave propagation and, for a given cut, with the strength of the driving shock. Observed Hugoniot elastic limits range from 45 to 90 kilobars in the x-cut crystals, 75 to 100 kilobars in the y-cuts, and 110 to 160 kilobars in the

z-cuts. Somewhat similar phenomena, with substantially lower elastic limits, are seen in fused quartz.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

Q5. Shock-Induced Luminescence of Quartz.* W. P. BROOKS AND F. W. NEILSON, *Sandia Corporation.*—When quartz is shocked near and beyond its Hugoniot elastic limits, an intense self-luminescence occurs (10^6–10^8 lumens/m^2). The threshold pressure, intensity, and pattern are distinct for the different axes of crystalline quartz and for amorphous quartz. The source of luminescence for amorphous quartz and for the z axis appears to be at cracking fronts propagating into the material from free surfaces and is believed to be the well-known triboluminescence. The source of luminescence for the $+x$, $-x$, and y axes, however, appears to occur at shock fronts and is believed to be associated with the piezoelectrically produced electric fields.[1] The most unusual behavior is the difference between the $+x$ and $-x$ axes. The luminescence for the $-x$ axis occurs at the lowest pressure and is the most intense. The initial pattern is an array of bright dots. The initial pattern for the $+x$ axis is two sets of parallel lines forming angles of 27° and 73° with the z axis.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] F. W. Neilson and W. B. Benedick, "The piezoelectric response of quartz beyond its Hugoniot elastic limit."

Q6. Piezoelectric Response of Quartz Beyond Its Hugoniot Elastic Limit.* F. W. NEILSON AND W. B. BENEDICK, *Sandia Corporation.*—X-cut quartz shocked in the x-direction continues to give an electrical output for shock pressures up to 300 kilobars. When shocked in the positive x-direction, the charge output increases slowly with pressure beyond about 50 kilobars; higher pressures primarily distort the output waveform. When shocked in the negative x-direction, the charge output reverses and becomes positive beyond about 50 kilobars. A proposed model for this behavior is based on the elastic-plastic double shock wave which has been found in quartz.[1] It is proposed that only the elastic zone responds piezoelectrically and that the plastic zone behaves as a relief of elastic distortion and electrical polarization. Beyond the elastic limit, unilateral conduction exists in the quartz according to the direction of the electric field relative to the shock fronts. When shocked in the positive x-direction, the plastic zone conducts, and the amplitude of the output is determined by the amplitude of the elastic wave. When shocked in the negative x-direction, the elastic zone conducts and the reversed output is due to the relieving plastic zone.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] J. Wackerle, Bull. Am. Phys. Soc. Ser. II, 5, 510 (1960), this issue.

Q7. Piezoelectric Behavior of Impacted Quartz.* R. A. GRAHAM, *Sandia Corporation* (introduced by G. W. Anderson).—The piezoelectric behavior of synthetic X-cut quartz has been investigated experimentally under conditions of transient stresses of from 5 to 40 kilobars. Of particular interest is a comparison of electrical charge release under impact conditions to low signal piezoelectric constants and a determination of the stress at which charge release ceases to be proportional to stress. Flat cylinders of X-cut quartz are impacted upon an X-cut quartz specimen whose X-axis is aligned parallel to the impact axis. The relations governing the elastic impact of flat surfaces and the Hugoniot conservation of momentum relation are utilized to determine the stress due to impact. The charge release from the quartz, as a consequence of the passage of the stress wave produced by impact, is observed on an oscilloscope. It has been found that the charge release ceases to be proportional to stress at a stress of 25 kilobars. The apparent charge to stress ratio is found to be dependent upon the specimen geometry. At high stresses this experimental ratio is generally greater than the low signal e_{11} constant, but for specimens with small thickness-to-diameter ratio the e_{11} relation is obtained.

* Work performed under U. S. Atomic Energy Commission contract.

Q8. Internal Friction of Crystalline Quartz at Low Temperatures. CLIFFORD K. JONES,* *Imperial College* (introduced by I. Rudnick).—The internal friction of a number of samples of synthetic crystalline quartz has been measured by a resonator technique, at a frequency of about 5 Mc, over the temperature range from about 4° to 150°K. It has been found that the magnitudes of the relaxation peaks reported by previous authors are significantly influenced by the growth rate of the material and by subsequent irradiation and thermal treatment. The effects of these experimental parameters on the internal friction peaks are consistent with, and give good support to, the proposed loss mechanisms involving the interaction of specific structural imperfections with the sound field.

* Now at the Department of Physics, University of California, Los Angeles 24.

Q9. Resistivity of Thin Metallic Wires.* F. J. BLATT AND H. G. SATZ,† *Michigan State University.*—Measurements by Olsen on thin indium wires have demonstrated that the residual and also the temperature dependent part of the resistivity increases with decreasing wire diameter. He suggested that small-angle electron-phonon scattering may account for the observed effect by scattering electrons to the surface where they suffer diffuse reflection. We have considered the problem, using basically the elementary approach of Nordheim, and obtain an additional resistivity given by

$$\rho_{ps} = (2\pi)^{\frac{1}{2}}\left(\frac{mv_F}{ne^2}\right)^{\frac{1}{2}}\left(\frac{T}{\theta_D}\right)^{\frac{1}{2}}[\rho_i^N(T)]^{\frac{1}{2}}(r)^{-\frac{1}{2}}; \quad r \ll l.$$

Here v_F is the Fermi velocity and $\rho_i^N(T)$ the ideal resistivity due to normal processes only. This expression agrees qualitatively and quantitatively with Olsen's results and also accounts for Andrew's observations. Careful measurements on thin wires may allow an experimental separation between the ideal resistivities due to normal and umklapp processes.

* Supported in part by the U. S. Air Force Office of Scientific Research.
† Present address: Physikalisches Staatsinstitut, Hamburg, Germany.

Q10. Excitation of Luminescence of a Solid by Nitrogen Atoms.* KENNETH M. SANCIER, WILLIAM J. FREDERICKS, AND HENRY WISE, *Stanford Research Institute.*—A solid lumophor such as CaO or MgO may be made to luminesce when nitrogen atoms recombine heterogeneously at its surface.[1] The recombination energy of the atoms transferred to the electronic and vibrational states of the solid is dissipated as luminescence and as heat. In order to elucidate the mechanism of the energy transfer and conversion the quantitative relationship between these energies was studied. The luminescent energy was measured by ferrioxalate actinometry, the heat developed in the lumophor by calorimetry, and nitrogen atom concentration by NO titration. The recombination coefficient of nitrogen atoms on a CaO lumophor also was determined. Calculations indicate that for each nitrogen atom which recombines to produce luminescence, from 100 to 1000 atoms (depending upon lumophor) recombine to produce heat. The fact that this ratio changes with time of exposure to atoms raises the possibility that light and heat may be produced by different catalytic mechanisms.

* Supported by the U. S. Air Force, Office of Scientific Research.
[1] K. M. Sancier, W. J. Fredericks, and H. Wise, J. Chem. Phys. **30**, 1355 (1959).

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Perez-Mendez, Victor—O9
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Portis, A. M.—A2, A6, E2
Post, R. F.—N5, N6
Pusterla, Modesto—M3
Reich, C. W.—C11
Rosenfeld, A. H.—O7
Ross, Marc H.—M2
Rothe, E. W.—L4
Rubinstein, M.—A2, L10
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Ruderman, H.—O3
Rustgi, Om P.—F6
Sachs, Mendel—M7, M8
Sah, C. T.—N7
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Satz, H. G.—Q9
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Schmidt, V. Hugo—H3
Schoen, Richard—F7
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Schwartz, Charles—L5
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Shaw, Gordon L.—M2
Shugart, H. A.—L7, L8, L11
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Silsbee, Henry B.—H3, H4
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Sloan, D. H.—I4

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Stapp, Henry P.—J11
Stephens, F. S., Jr.—P1
Streever, Ralph L., Jr.—A5
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Townes, Charles H.—H1
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Van Lint, V. A. J.—L3
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Walstedt, R.—H10
Warnock, Robert Lee—M3
Warshaw, S. D.—I9
Warwick, James W.—B3
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Willis, W. J.—O2
Winckler, John R.—I2
Wise, Henry—F1, Q10
Wood, Calvin D.—O9
Yamamoto, S. S.—O2
Young, J. A.—M11

Preliminary Announcement of the 1961 Annual Meeting

The 1961 Annual Meeting of The American Physical Society will be held in New York City on Wednesday, Thursday, Friday, and Saturday, February 1, 2, 3, and 4, 1961. As usual, The American Association of Physics Teachers will hold concurrent sessions and there will be a joint ceremonial session of the two societies comprising our retiring Presidential address and the Richtmyer lecture and Oersted Prize presentation of the AAPT.

There will be a business meeting of our Society. The official hotel for the meeting will be the New Yorker (New York 1, New York). It is advisable to make your reservations for this meeting as early as possible. You should write to the Hotel New Yorker and mention that you are coming to a meeting of the Society.

The scientific sessions for the meeting will be held in or near the Hotel New Yorker. Deadline is past

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Second Announcement of the 1961 March Meeting in Monterey

The 1961 March meeting will be held at the U. S. Naval Postgraduate School in Monterey, California, on Monday, Tuesday, and Wednesday, March 20, 21, and 22. Additional sessions will be held on Thursday, March 23, by the Division of High-Polymer Physics (see the separate announcement in this Bulletin concerning the Division of High-Polymer Physics). The Divisions of Solid-State Physics and Chemical Physics also will be featured, mainly during the regular three-day sessions.

Accommodations will be available at the following hotels: Mark Thomas Inn and Casa Munras. Motel rooms also will be available in the area. Members are urged to write as soon as possible for room reservations to the Monterey Peninsula Convention Bureau, P. O. Box 1571, Monterey, who are acting as agents. Be certain to state that you are attending the meeting of The American Physical Society. A committee consisting of Professors J. R. Neighbours, *Chairman*, J. N. Cooper, and L. O. Olsen of the U. S. Naval Postgraduate School has been formed to organize the local arrangements.

Abstracts for the meeting should reach the office of the Deputy Secretary for the Pacific Coast, Professor E. L. Hahn, Department of Physics, University of California, Berkeley 4, no later than January 13, 1961.

1961 Meeting of the Division of High-Polymer Physics

The Division of High-Polymer Physics will convene at Monterey, California, at the general meeting of the Society on March 21 and 22 with additional sessions on March 23. Abstracts for this Divisional meeting should be sent to Dr. David W. McCall, Bell Telephone Laboratories, Inc., Murray Hill, New Jersey, and must be received in Dr. McCall's office by Friday, January 6, 1961. This date is one week in advance of the deadline for the regular meeting of the Society. The abstracts for the Divisional meeting must conform to the same regulations as are imposed on those submitted for meetings of the Society. Abstracts in high-polymer physics that are sent to the Deputy Secretary for the Pacific Coast will be woven into the programme somehow but probably will not be so well placed as though they had gone to Dr. McCall.

Contributions for this Division should not be confused with abstracts submitted for the regular Society meeting. Abstracts for the latter should be submitted to Professor E. L. Hahn, University of California, Berkeley 4, California.

Topical Conference on Strong Interactions

THE programme for the **Topical Conference on Strong Interactions** to be held Tuesday, Wednesday, and Thursday, December 27, 28, and 29, 1960, will be found on page 516 of this Bulletin. Support for this Conference has been provided by the U. S. Atomic Energy Commission and the U. S. Air Force Office of Scientific Research. The meetings in the first two days will be held in Le Conte Hall (the Department of Physics Building) at the University of California in Berkeley. The Thursday meetings are to be held in Wheeler Auditorium, a few minutes' walk from Le Conte Hall.

The Committee in charge of the Conference has arranged a programme consisting of invited papers on experimental results on Tuesday and Wednesday and invited papers on theory on Thursday. The program on Wednesday afternoon has been purposely kept short so that there will be time for visits to the Lawrence Radiation Laboratory and informal discussions.

Those attending the Conference will be asked to register in the lobby of Le Conte Hall, preferably on Tuesday morning (fee $1). This also will serve as registration for The American Physical Society meeting on Thursday, Friday, and Saturday.

A cocktail party for those attending the Conference on Strong Interactions will be held in the Horizon Room of the Claremont Hotel, Berkeley, on Wednesday, from 5:00 to 7:00 p.m. Sponsorship of the party is partially due to the generosity of a number of industrial firms on the West Coast and will be indicated on tickets for the cocktail party.

The committee in charge of this Conference consists of V. F. Weisskopf, W. K. H. Panofsky, R. L. Cool, G. F. Chew, D. A. Glaser, and A. C. Helmholz, *Chairman*. Inquiries should be addressed to A. C. Helmholz, Department of Physics, University of California, Berkeley 4.

Conference on Strong Interactions

PROGRAMME

TUESDAY MORNING AT 9:30

310 Le Conte Hall

(A. C. HELMHOLZ presiding)

Elementary Cross Sections

1A. 310-Mev π^+-p Polarization and Cross-Section Experiments: Phase-Shift Analysis. E. H. ROGERS, *Lawrence Radiation Laboratory.* (30 min.)

1B. π-p Work at Saclay. PAUL FALK-VAIRANT, *Centre d'Etudes Nucléaires de Saclay.* (45 min.)

1C. Differential π^--p Cross Sections in the Region of the Higher Resonances. B. J. MOYER, *Lawrence Radiation Laboratory.* (30 min.)

1D. Production of Mesons and Hyperons in Hydrogen by Positive Pions. E. C. FOWLER, *Yale University and Brookhaven National Laboratory.* (40 min.)

TUESDAY AFTERNOON AT 2:00

310 Le Conte Hall

(W. K. H. PANOFSKY presiding)

Elementary Cross Sections

2A. Interactions of K^0 Mesons in Flight. R. K. ADAIR, *Yale University and Brookhaven National Laboratory.* (40 min.)

2B. Recent Work on Strong Interactions at CERN. A. M. WETHERELL, *CERN.* (50 min.)

2C. K^--p Hydrogen Chamber Experiments. MAX FERRO-LUZZI, *Lawrence Radiation Laboratory.* (40 min.)

2D. K-Nucleon Interactions. LEROY KERTH, *Lawrence Radiation Laboratory.* (40 min.)

WEDNESDAY MORNING AT 9:00

310 Le Conte Hall

(D. A. GLASER presiding)

Interactions in the Final State

3A. Double Meson Production in $p+d$ Collisions. A. ABASHIAN, *Lawrence Radiation Laboratory.* (30 min.)

3B. Final States of the $\bar{p}$-p System. G. R. LYNCH, *Lawrence Radiation Laboratory.* (20 min.)

3C. π-π Correlations in $\bar{p}$ Annihilation. W. CHINOWSKY, *Brookhaven National Laboratory and Lawrence Radiation Laboratory.* (30 min.)

3D. Excited Hyperons. MARGARET ALSTON, *Lawrence Radiation Laboratory.* (30 min.)

3E. π-π Interactions. P. G. BURKE, *Lawrence Radiation Laboratory.* (20 min.)

WEDNESDAY AFTERNOON AT 2:00

310 Le Conte Hall

(R. L. COOL presiding)

A Cusp at Σ Threshold

4A. (Title to be announced.) A. M. SCHWARTZ, *Columbia University and Brookhaven National Laboratory.* (45 min.)

4B. (Title to be announced.) F. S. CRAWFORD, JR., *Lawrence Radiation Laboratory.* (30 min.)

THURSDAY MORNING AT 9:00

Wheeler Auditorium

(V. F. WEISSKOPF presiding)

Theory of Strong Interactions

5A. Analyticity and Unitarity as a Basis for Strong Interaction Theory. STANLEY MANDELSTAM, *University of Birmingham.* (45 min.)

5B. Anomalous Thresholds. R. E. CUTKOSKY, *Carnegie Institute of Technology.* (45 min.)

5C. Recent Progress in the Dispersion Theory of Pion-Nucleon Interactions. SERGIO FUBINI, *CERN and University of Padua.* (45 min.)

THURSDAY AFTERNOON AT 2:00

Wheeler Auditorium

(Stanley Mandelstam presiding)

Theory of Strong Interactions

6A. Strong Interactions of Strange Particles. R. H. DALITZ, *University of Chicago.* (45 min.)

6B. Peripheral Contributions to High-Energy Interaction Processes. S. D. DRELL, *Stanford University.* (45 min.)

6C. A Unified Dynamical Approach to High- and Low-Energy Strong Interactions. G. F. CHEW, *Lawrence Radiation Laboratory.* (45 min.)

Author Index to Papers Presented at the Conference on Strong Interactions

Abashian, A.—3A
Adair, R. K.—2A
Alston, Margaret—3D
Burke, P. G.—3E
Chew, G. F.—6C
Chinowsky, W.—3C
Crawford, F. S., Jr.—4B
Cutkosky, R. E.—5B
Dalitz, R. H.—6A
Drell, S. D.—6B
Falk-Vairant, Paul—1B
Ferro-Luzzi, Max—2C
Fowler, E. C.—1D
Fubini, Sergio—5C
Kerth, Leroy—2D
Lynch, G. R.—3B
Mandelstam, Stanley—5A
Moyer, B. J.—1C
Rogers, E. H.—1A
Schwartz, A. M.—4A
Wetherell, A. M.—2B

MEETINGS AND DEADLINES THROUGH AUTUMN 1961

Place	*Meeting dates*	*Deadline date*
New York	February 1–4, 1961	Past
Monterey*	March 20–23	January 13
Washington	April 24–27	February 10
Mexico City	June 22–24	undecided
Chicago	November 24–25	undecided
Los Angeles*	December 27–29	undecided
New York	January 24–27, 1962	undecided

Abstracts for the meetings marked with asterisks are to be sent to Professor E. L. Hahn, University of California, Berkeley 4, California, and must reach his office not later than the corresponding deadline date. Abstracts for the other meetings listed above are to be sent to Karl K. Darrow, American Physical Society, Columbia University, New York 27, New York, and must reach his office not later than the corresponding deadline date. Take note that abstracts mailed the day before deadline day often fail to arrive in time: the last postal delivery of the day usually comes to our office before 2 p.m. *Allow at least two days for abstracts sent by airmail from points east of the Mississippi, and longer for those sent from farther west.* Abstracts postmarked (at the point of dispatch) on deadline day are instantly rejected. No abstract postmarked (at the point of dispatch) on deadline day ever reaches the office on time, nor does any abstract postmarked at any point west of the Rockies on the day before deadline day. Some abstracts arrive with covering letters dated three or more days before the postmark; it may be a good idea for you to put your abstract into a United States mail box with your own hands. *The privilege of contributing papers to meetings of The American Physical Society is restricted to the members of the Society and to nonmembers whose papers are sponsored by members.*

DIVISIONAL MEETINGS AND TOPICAL CONFERENCES (see pages 514 and 515)

Berkeley	Strong Interactions	December 27–29	Past
Monterey	High-Polymer Physics	March 21–23	January 6

RULES AND INSTRUCTIONS FOR THE PREPARATION OF ABSTRACTS

The Council has ordered that abstracts shall be not longer than two hundred (200) words or the equivalent thereof. In reckoning equivalence, a footnote is equated to ten words or to its actual length in words, whichever is the greater; each line in a table to ten words; a "display" formula—one that requires a line to itself—is an expensive luxury equated to forty words.

Two copies of each abstract must be sent to the appropriate office. They must be typewritten; *one must be an original*, the other may be an original or a carbon copy. *Carbon copies will not be accepted in lieu of originals:* they smear. *Abstracts must be double-spaced:* single-spaced manuscripts are too crowded to permit the editorial markings to be made with ease and clearness. *Each abstract must be confined to a single page:* if it is too long for a single page it is too long to be printed. If we receive an abstract typed on two pages, we print only its first page. *Write each abstract as a single paragraph:* the suppression of paragraphs costs time and labor to the editors. *Do not use very thin paper:* a sheet of very thin paper may cause extraordinary trouble when mixed with sheets of reasonable thickness. *Tables too broad to fit in a single column of this bulletin will be deleted.* The American Institute of Physics will bless you if you type first the title of your abstract in lower-case with capitalized initials, then your name in capitals, then the name of your institution in lower-case underlined with capitalized initials. It is a pleasure to report that those who qualify for this blessing are increasing in number but are still quite a bit short of 100% of the total. Issues of the *Bulletin* are always appreciably delayed because the editors have to do what the authors should have done.

Remember the rule of the Council that, if an author submits more than one abstract, all but one must go onto the Supplementary Programme. In enforcing this rule, an abstract is credited to the author whose name appears first in the by-line.

It has now become an expensive business to make any change in an abstract, even the smallest, after the abstract has gone to press. By order of our Council "A change in an abstract will be permitted only at the discretion of the Secretary or his deputy, and only if TEN DOLLARS is enclosed with the letter in which the change is requested." As heretofore, an abstract will not be withdrawn from proof unless the asker sends ten dollars with his request.

New Instructions

(*a*) *If it is wished that two abstracts be scheduled consecutively, write on the first "To be scheduled before abstract ..... by ....." and on the second "To be scheduled after abstract ..... by ....."*

(*b*) *If a member insists that his paper be scheduled for a particular day or not on a particular day, he will get his wish, but usually at the price of having his contribution included in a session to which it is irrelevant.*

(*c*) *The Secretary and his deputies have been empowered by the Council to count a footnote either as ten words or as its actual length in words, whichever is the greater length.*

(*d*) *In general, all instructions about an abstract should be typed at the bottom of the page that has the abstract on it,* never *in a covering letter. Covering letters get separated from abstracts!*

(*e*) *Always write your name the same way. Do not use initials in one abstract and then spell it out in another. This complicates indexing. It is preferable to give your name in full.*

The American Physical Society

OFFICERS OF THE SOCIETY FOR 1960

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